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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

FIRST ANNUAL REPORT

OF THE

RECLAMATION SERVICE

FROM

JUNE 17 TO DECEMBER 1, 1902

F. H. NEWELL
Chief Engineer

WASHINGTON
GOVERNMENT PRINTING OFFICE
1903

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LETTERS OF TRANSMITTAL.

Department of the Interior,
Washington, December 3, 1902.

Sir: Pursuant to the requirement of section 2 of the act of Congress entitled "An act appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands," approved June 17, 1902 (32 Stat. L., 388), I have the honor to inclose a report of the Director of the Geological Survey, showing the work done and in progress thereunder.

In view of the short time that has elapsed since the passage of said act, it is impossible to show in this report "the quantity and location of the lands which can be irrigated" from the various projects under consideration, or "the cost of works in process of construction, as well as of those which have been completed," for the reason that no works are now in process of construction or have been completed.

In summarizing the work done since the passage of the act, the Director says:

> The more important or more obvious opportunities for reclamation are being examined. Large areas of land have been temporarily withheld from settlement, excepting under the homestead law, and the lands not needed will be restored to general entry as rapidly as the final plans can be made. The plans, estimates, and specifications are being prepared, and some of them will undoubtedly be ready for submittal in the early spring.

Very respectfully,
E. A. Hitchcock,
Secretary.

The Speaker of the House of Representatives.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C., November 29, 1902.

SIR: I have the honor to transmit herewith a report of the work done and in progress under the reclamation law approved by the President on June 17, 1902, together with other information essential to the full understanding of the subject. During the five months which have elapsed since the passage of this law, field work has been actively carried on in various States by men who before that time were engaged in similar operations, and by other skilled engineers who have been found available.

As preliminary to the details of engineering work, there is given a brief discussion of the arid public lands and of the importance of these to the nation. A series of maps shows the location and extent of these lands in each of the Western States and Territories, and the areas still in public ownership. The preparation of these maps is, in effect, a taking account of stock of the real estate assets of the Government. Not only is it necessary to know how much land is left and where this is situated, but also the probabilities as regards the disposal of this land and the future increase of the reclamation fund.

Mention is also made of the events of general interest which preceded the passage of the reclamation law and which in one way or another showed the trend of public opinion. The effective carrying out of such a law as this is, in some degree, dependent upon the attitude of the public toward the law, and this is perhaps best shown by the events which made possible the consideration of the preliminary legislative bills.

The laws recognizing irrigation and to a certain extent paving the way for the existing act are also briefly mentioned, as these have served to modify the conditions under which the act can be operated. They also exhibit the attitude of Congress toward national irrigation works.

The reclamation law itself is quoted in full, together with comments upon its scope and upon the details, which are left largely to Executive action. The law is so general in its terms that its success or failure may be said to rest almost wholly upon its administration. Congress has practically committed the whole matter to the Secretary of the Interior, and a volume might be, and probably at some time will be, written regarding the almost innumerable details which are not touched upon in the law.

The work of examination and survey is described by States. A large amount of preliminary work has been carried on by the Geological Survey, anticipating, in a sense, the passage of the reclamation law; and these preliminary surveys, where continued under the existing law, are described in connection with the operations since last June. In most instances the field work is still in progress, and there has not been opportunity for the men in the field to write up results or make necessary computations. In nearly every locality there are alternative methods of reaching the desired end, the relative merits of which can not be determined until careful estimates have been made. It is intended to complete these as rapidly as possible, and it is hoped that by the end of the winter season specific recommendations leading up to the letting of contracts can be made. At the present time, however, it is premature to offer more than a statement of the work in hand, with such plans or tables of estimates as have been finished, but without attempting to summarize or compare the results or to make a final recommendation.

In brief, it may be stated that work has been carried on in the following localities in the various States and Territories: On Salt and Gila rivers in Arizona; on Colorado River in California; on North Platte, Gunnison, and Grand rivers in Colorado; on Snake River in Idaho; on the deep-well problems of western Kansas; on Milk River in Montana; on the artesian-well probabilities of western Nebraska; on the Carson and Truckee rivers in Nevada; on the artesian probabilities of central Oregon; on Bear River in Utah; on Yakima River in Washington; around Lake De Smet and also on Sweetwater River in Wyoming.

At each of the places where systematic work has been carried on, preliminary temporary withdrawals of vacant public lands have been made. The extent of these withdrawals is changing from time to time, the outlines being modified as occasion demands. The ultimate area which may be reclaimed bears no relation to the lands thus temporarily segregated, as in many instances alternative projects are being considered, and it is necessary to run trial lines over a large extent of country before the portion which may ultimately be reclaimed can be determined upon.

The final determination of the reclaimable area rests upon a summation of all of the facts of feasibility and cost, so that it can be stated only as the last of a series of estimates. That is to say, in each project the conditions are being sifted down to a condition where judgment must be exercised whether, for instance, it is better to reclaim a certain body of good land at a cost of $12 per acre or a larger body of less valuable land at $10 per acre. This final judgment can only be passed when all of the facts of cost of each detail, expense of maintenance, the permanence of structures, and character of soil and climate have been worked out with great care.

The fact that it is impossible to state in advance the plans which ultimately may be recommended for reclamation is leading to what will result in great disappointment to many persons. The fact that lands have been temporarily set aside is, in the eyes of many, an indication that these lands will be reclaimed; and although every attempt has been made to warn individuals of the futility of filing upon these lands under the homestead law, yet they persist in taking up the land on the bare possibility that the surveys and examinations will ultimately show these lands to be reclaimable. It is an unfortunate condition, which apparently can not be corrected at present. The surveyors must traverse great areas before they can select the best projects, and it is essential to reserve the land in advance of their going into the field. Otherwise criticism will arise that necessary care has not been used to carry out the intent of the law.

In summarizing the work of the five months it may be said that the more important or more obvious opportunities for reclamation are being examined. Large areas of land have been temporarily withheld from settlement, excepting under the homestead law, and the lands not needed will be restored to general entry as rapidly as the final plans can be made. The plans, estimates, and specifications are being prepared, and some of them will undoubtedly be ready for submittal in the early spring.

Very respectfully,
Chas. D. Walcott,
Director.

The Secretary of the Interior.

Department of the Interior,
United States Geological Survey,
Reclamation Service,
Washington, November 29, 1902.

Sir: The reclamation law, dated June 17, 1902, section 2, instructs the Secretary of the Interior—

> To report to Congress at the beginning of each regular session as to the results of such examinations and surveys, giving estimates of cost of all contemplated works, the quantity and location of the lands which can be irrigated therefrom, and all facts relative to the practicability of each irrigation project; also the cost of works in process of construction as well as of those which have been completed.

In accordance with this law and with the plan approved by the Secretary of the Interior on July 8, 1902, I have the honor to submit the accompanying manuscript, being the First Annual Report of the Reclamation Service, embracing the operations for the greater part of the calendar year 1902.

Very truly, yours,
F. H. Newell,
Chief Engineer.

Hon. Charles D. Walcott,
Director of United States Geological Survey.

FIRST ANNUAL REPORT

OF THE

RECLAMATION SERVICE.

F. H. NEWELL, *Chief Engineer.*

INTRODUCTION.

On June 17, 1902, the act of Congress appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigating works for the reclamation of arid lands became a law. On the following day a plan for beginning work under this law was submitted to the Secretary of the Interior by the Director of the Geological Survey. This plan, approved on July 8, authorized the creation of the "Reclamation Service," the sum of $165,000 being at the same time set aside for use in beginning the necessary surveys and examinations.

One of the first acts required by the law is the temporary withdrawal of lands which are to be reclaimed, in order to prevent speculative filings upon them pending their examination. On June 28 a list of lands in six different localities was submitted, as follows:

Nevada	Truckee-Carson survey.
California and Arizona	Colorado River survey.
Arizona	Salt River survey.
Colorado	South Platte survey.
Colorado-Utah	Grand River survey.
Wyoming	Bighorn survey.

Certain lands to be benefited had previously been temporarily withdrawn, by order of the Secretary of the Interior, viz, in Montana, under the St. Mary project; in Arizona, under the San Carlos project; and in Colorado, under the Gunnison project.

As soon as these withdrawals had been determined upon, the field parties of the Reclamation Service were instructed to begin the necessary surveys, and steps were taken to push forward the examinations as rapidly as possible. The operations were greatly facilitated by the fact that the work was not new to the men in charge, and that they were able to follow the methods and precedents established by the Geological Survey during twenty years of field work.

The Reclamation Service, organized for the purpose of making surveys and examinations required by the law of June 17, 1902, and for putting into effect the various projects authorized by that law, has been created by the Secretary of the Interior, temporarily at least, as a part of the Hydrographic Branch of the Geological Survey. The preliminary work contemplated by the law has been carried on for a number of years by this Bureau, and at the time of the passage of the law the investigations were well under way in connection with the operations of the Division of Hydrography. The plan approved by the Secretary proposed to gradually enlarge and increase the number of parties in the field without otherwise disturbing the current operations. The engineers of the Hydrographic Branch were selected through competitive examination and have been advanced because of experience and efficiency. Additional young engineers have been asked as needed from the Civil Service Commission, and temporary field assistants have been employed under existing rules and regulations.

The advantages derived from this course of action have been very great, since it has been possible thus to push forward the field work and extend it along lines already tried and proved successful. The organization of a new bureau, involving the employment of men not accustomed to the work and not familiar with Government methods, and the laying down of methods and regulations for an untried system, is usually slow and unsatisfactory. There are innumerable matters, such as accounts, reports, personnel, and ways and means, in which a mistake means serious delay. To be able to start a work with all of these well established means a gain of at least a year in efficient progress.

The men employed in the Reclamation Service are primarily those who have been investigating the extent to which the arid lands can be reclaimed by irrigation, as authorized by act of Congress of October 2, 1888. These men have spent the greater part of their lives in the West in the consideration of problems of water storage, stream measurements, and irrigation development. The additional men secured through the Civil Service Commission have been selected from the lists of those persons eligible to appointment as irrigation engineers or assistants, or as junior civil engineers or assistant topographers. An excellent class of well-educated, efficient, and energetic young men is available. There have been many applications for employment without preliminary tests, but it is deemed absolutely essential for the success of the work to select assistants by competitive examination and to advance all of the men solely on the basis of merit and ability.

From the time that the reclamation bill became a law investigations in various States have been pushed as rapidly as possible, with the purpose of ascertaining what reclamation projects are most feasible, and of obtaining facts upon which to base a recommendation to the

Secretary of the Interior for the immediate construction of one or more of these projects, and to suggest methods by which the cost of each project will be returned to the Treasury. In taking up each survey or examination, consideration has been given to the opportunities offered, as well as to the desires of the people as expressed by petitions or requests. In deciding what should be done, however, the feasibility of each project as shown by present knowledge has alone been considered. It is believed that the consideration of any questions other than those of intrinsic merit and probability of an early refunding of the cost will endanger the future of the work.

ARID PUBLIC LANDS.

The reclamation fund is derived from the receipts from the sale and disposal of public lands in thirteen States and three Territories, which embrace the entire arid region of the United States. The only arid portion not included is in the State of Texas, the western end of which extends beyond the region of humidity. In this State, however, there are no public lands belonging to the United States, as Texas upon admission to the United States retained control of the vacant lands included within its boundaries. The relative positions of the States and Territories affected by the reclamation law are shown in fig. 1.

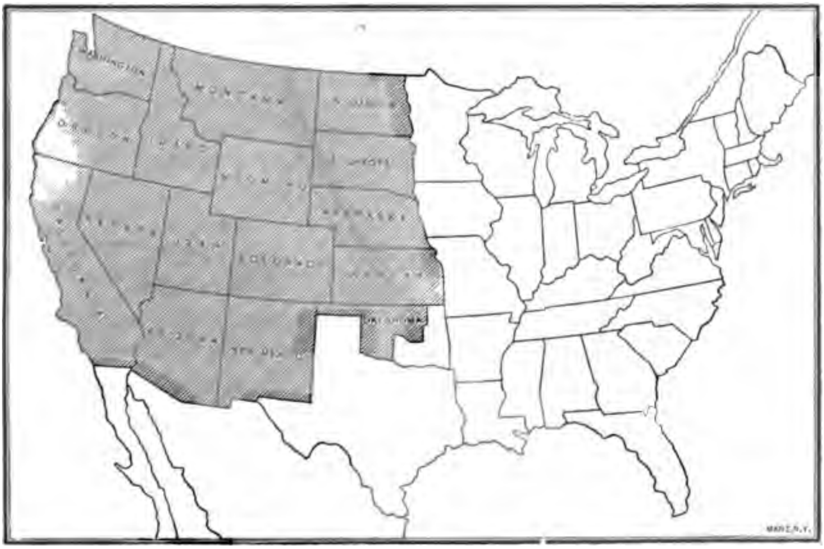


FIG. 1.—Map of States included in reclamation law.

LOCATION AND PORTIONS VACANT.

Not all of the arid lands which can be reclaimed are still vacant; many of them have passed, in whole or in part, into the hands of private owners. The greater portion of these are included within grants to railroads, for the purpose of aiding in the construction of transcontinental lines, or are covered by the Spanish land grants recognized by treaty with Mexico. Tracts have also been donated to States for various purposes. Many homestead and other entries have been made along the banks of rivers or around springs or other sources of water supply. The problem of reclamation is therefore not simply one of dealing with public land, but is complicated by private ownership.

As a rule it may be said that practically all of the land now remaining in the hands of the Government is arid. The principal exceptions to this are the timbered areas, mostly mountainous, near the Pacific coast. These, however, are being rapidly taken up in the interest of lumber companies, and it is improbable that tracts of land covered with trees and outside of the limits of the forest reserves will be left vacant for any considerable time.

One of the first matters for investigation in any general consideration of the reclamation of the arid lands is their location, the portions vacant, and the relation of these to present development. For this purpose maps showing the vacant public lands have been prepared. These were begun as soon as it became apparent that such information would be needed, and they were well under way some time before the passage of the law. On these maps the lands disposed of by the United States are shown in black. They have been prepared in most cases from data furnished by the General Land Office. It was impossible to decide definitely as to the status of each tract, but in the appropriated lands are included all tracts for which the records showed any claim, regardless of the fact that in many instances such claim was in process of adjudication by the Land Office. The areas appropriated are increased by thousands of acres day by day as entries are made under public-land laws; changes are being constantly made in the lands reserved, and many tracts for which applications may have been made under the public-land laws, and which are shown in black on these maps, will, for various reasons, be restored to the public domain and be included later in the class of unappropriated and unreserved lands. In spite of these sources of error, the maps afford a close approximation to the general condition of the lands in the various States and Territories. They can by no means be regarded as accurately expressing the conditions at the present time; but they give an excellent representation of the conditions at the time of compiling the data.

To present a general statement of the amount of land (1) reserved, (2) appropriated, and (3) unappropriated and unreserved, the following table is inserted, as showing the conditions existing on June 30, 1902. The amounts of land reserved and appropriated are taken from the report of the Commissioner of the General Land Office for the year 1902:

Areas of reserved and appropriated lands in the reclamation States on June 30, 1902.

[Compiled from Report of Commissioner of the General Land Office.]

State.	Unreserved and unappropriated.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Arizona	46, 770, 142	19, 724, 717	5, 773, 941	72, 268, 800
California	41, 409, 714	16, 033, 270	42, 384, 216	99, 827, 200
Colorado	38, 409, 052	5, 658, 303	22, 265, 445	66, 332, 800
Idaho	42, 954, 819	1, 331, 311	9, 659, 470	53, 945, 600
Kansas	884, 888	987, 875	50, 415, 237	52, 288, 000
Montana	60, 844, 314	14, 999, 417	17, 154, 669	92, 998, 400
Nebraska	9, 021, 177	606, 611	39, 549, 812	49, 177, 600
Nevada	61, 196, 778	5, 983, 409	3, 053, 413	70, 233, 600
New Mexico	55, 102, 716	6, 385, 181	16, 886, 503	78, 374, 400
North Dakota	15, 086, 197	3, 325, 490	26, 513, 113	44, 924, 800
Oklahoma	3, 866, 776	3, 754, 849	17, 229, 575	24, 851, 200
Oregon	31, 114, 631	5, 878, 411	23, 525, 358	60, 518, 400
South Dakota	11, 361, 013	12, 791, 676	25, 031, 311	49, 184, 000
Utah	42, 168, 639	5, 574, 068	4, 858, 893	52, 601, 600
Washington	11, 129, 581	10, 546, 165	21, 127, 454	42, 803, 200
Wyoming	43, 798, 033	10, 773, 662	7, 876, 305	62, 448, 000
Total	515, 118, 470	124, 354, 415	333, 304, 715	972, 777, 600

The arid regions of the United States, as generally designated, include about two-fifths of its entire area, extending from about the middle of the continent westerly nearly to the Pacific Ocean. There are no sharply marked lines or divisions between the arid and the humid areas, but there is, especially near the center of the United States, a broad intermediate belt, neither distinctly arid nor distinctly humid, which is called the subhumid or semiarid region. This belt extends over North Dakota, South Dakota, western Nebraska, and western Kansas into Oklahoma and the panhandle of Texas. In years of excessive moisture the subhumid region sometimes creeps up toward the foothills of the Rocky Mountains, while during dry years the greater part of the plains region west of the Missouri becomes semiarid. The relative extent of the regions of aridity is shown in fig. 2.

In a general way it may be said that the arid regions are those where the average annual rainfall is 20 inches or less. The arid regions of the United States, therefore, are but a portion of those of North America, there being large tracts of arid lands in Mexico on the south and in Canada on the north. In these countries the Government has already recognized the importance of irrigation, and provision has been made for the reclamation of arid lands under public auspices. The Congress of the United States, in passing the reclamation law, has thus not been wholly without a precedent from other parts of the continent.

Aridity, or, rather, the unequal distribution of moisture, is largely the result of topography, or inequalities of land surface. If the globe were entirely flat it is probable that the winds, meeting with no obstructions, would distribute the rains with considerable uniformity in broad bands approximately parallel to the equator. The atmosphere enveloping the earth extends outward for many miles, but it is in the relatively thin and dense layer a mile or two in thickness resting immediately upon the surface that occur the changes or disturbances that make up what we know as weather. This thin layer of dense atmosphere surrounding the globe is disturbed in its uniform movement by the lofty mountain masses which traverse the continents. The movements of the air above this layer concern us little; it is the clouds and winds near the surface that bring success or failure to the farmer, and affect, more or less directly, other industries, and even health.

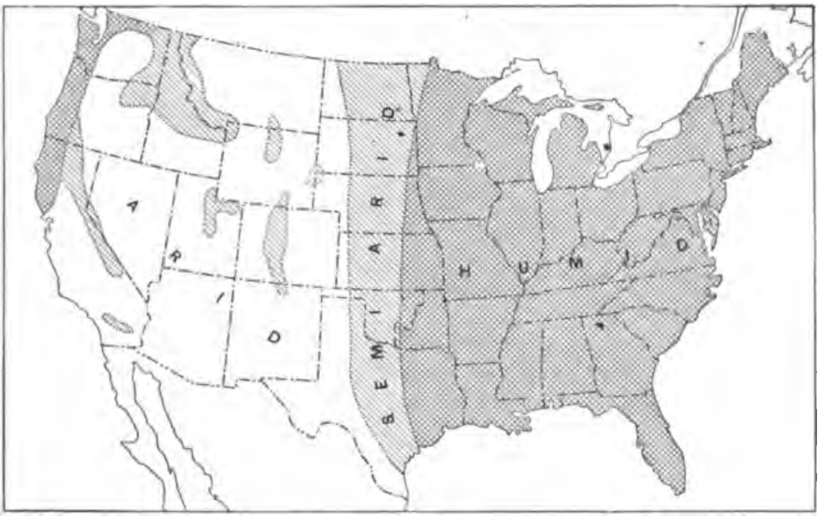


FIG. 2.—Map showing arid, semiarid, and humid regions of the United States.

Taking the United States as a whole, the general movement of the atmosphere is from west to east. The moisture-laden winds from the Pacific, encountering the mountain masses which extend along or parallel to the coast, are forced upward and cooled. In winter they deposit much of their moisture on the mountains, and then pass eastward as dry winds, leaving the broad plains east of the Sierra Nevada dry, sterile, and desert-like in character. In the summer, however, when the mountains have become relatively warm, the winds from the Pacific pass over them without leaving their moisture, and thus there results the summer drought characteristic of the Pacific coast. Passing onward, the winds, not deprived of humidity, give up from time to time portions of their precious fluid, and thus in the interior there are the occasional summer rains which tend to make amends for the deficient precipitation of the winter season. East of the Sierra Nevada and the Coast Range, and the plains and deserts at their bases, are scattered irregular mountain ranges and the great Cordillera or Rocky Mountain system, whose high summits intercept the rain-bearing winds. These mountain ranges are for the most part well watered while the lowlands are parched with drought. From the east face of the Rocky Mountains the high plains stretch out toward the Mississippi Valley, decreasing gradually in altitude to the rolling plains and prairies of the east-central States.

The above statements briefly outline what is known concerning the causes of aridity and the lack of uniformity of distribution of moisture across the continent. There are not only wide differences in various parts of the West and changes in succeeding seasons, but also great fluctuations in the quantity of rainfall from year to year. The actual excess or deficiency of rainfall as measured in inches may not seem great to the inhabitants of the humid East, but in the West when a shortage occurs the effects of the aridity are notably increased, and a large amount of water is needed to supply artificially the deficiency. Equal fluctuations in rainfall may occur in humid regions, but there the effects are not so marked. For example, in a country like that along the Atlantic seaboard, where the annual precipitation averages 50 inches, a deficiency of 10 inches during the year may not have an appreciable effect upon the crops and industrial conditions, but in a country where the annual rainfall is only 20 inches a deficiency of 10 inches may result in the disappearance of rivers and the destruction of the scanty vegetation so valuable in the cattle and sheep industries.

In the humid East the impression is rather general that aridity implies desert conditions, i. e., absence of vegetation, with naked rocks and sand glistening in the brilliant sunshine. On the contrary, the area of actual desert lands in the United States is relatively small. To the west of Great Salt Lake is what may be termed a true desert of sand and alkali, destitute of vegetation, except a few thorny or woody plants which occur at intervals; and in southern California, west of the Colorado River, is the Salton Desert, which embraces the bottom of an ancient arm of the Gulf of California, the land surface being in some places 300 feet below sea level, but shut off from the tides by the bars and ridges of mud brought down by the river. It is estimated that there are 70,000,000 acres of desert-like lands in the United States, areas which do not support any plants suitable for forage. The remainder of the arid regions is covered with a more or less scanty vegetation of some value to mankind.

One-third of the United States, exclusive of Alaska and outlying possessions, consists of vacant public land. One of the great economic questions now before the people of the country is the utilization of this vast area, much of which has a rich soil, and under good management would be capable of sustaining a large population. These lands, however, have not been utilized to any considerable extent for the making of homes, but are passing into the control of speculators or large landowners.

The public lands are open to entry and settlement under what is known as the homestead law, the intent and purpose of which is to provide homes for the rapidly increasing population and permit an extension of the agricultural area as rapidly as the needs of the people demand. The object of the law is, however, not being accomplished, because of the fact that the lands are for the most part within the arid region, and crops can not be produced until a water supply has been obtained sufficient to moisten the soil during the growing season. There is a large amount of water that can be thus employed, but the expense of utilizing it is too great for the settler. The lands in localities where water can easily be diverted to the thirsty soil were taken up by the pioneers. In the early days it was possible for a man with a team and ordinary farm tools to construct ditches leading from the creeks flowing out of the mountains, and thus to provide channels by which his farm could be irrigated. In this way he was able to produce crops on the lowlands along the rivers, and gradually to extend the system of water supply to even the adjacent terraces or bench lands. The later comers, however, find that the small streams are already fringed with farms, and that the land lying beyond, although in many cases of better quality, can not be watered except at great cost.

The laws governing the disposal of public lands have been drawn almost wholly with reference to the broad prairies and plains of the Mississippi Valley, where the rainfall is sufficient to mature the crops. In that flat or gently rolling country every tract of 160 acres is practically as good as its neighbor, small differences of soil and surface erosion being excepted, and each farmer is independent as regards his method of cultivation, conducting his operations in the manner that his experience dictates. In the great arid region, however, where lies the larger part of the unoccupied public lands (see fig. 3), the value of the farm depends almost wholly upon the water supply, the accessibility and permanence of which far outweigh all other conditions. There the interests of all the farmers are closely related, for all depend upon streams or other sources of supply used in common, and independence must give way to cooperation. While the lands may be equally good as regards soil, their value may be far different because of the fact that one tract of land has more water than another, so that the man who controls the water virtually owns everything of value. This fact has not been sufficiently recognized in framing laws governing the disposal of the public lands, and the result is that in many localities water monopoly is a powerful factor. In numerous instances title to a few hundred acres has virtually given possession to thousands of other acres, because the latter are rendered practically valueless by being cut off from participation in the water supply. In other words, the creation of hundreds of homes has been prevented by neglecting to guard the right to the use of the scanty supply of water.

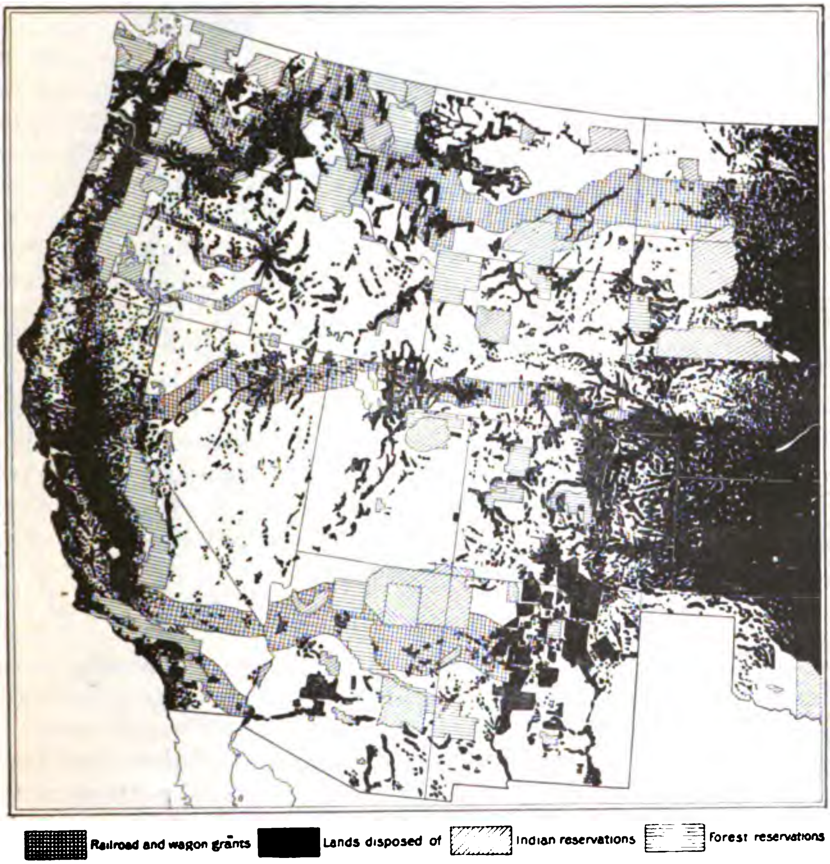


FIG. 3.—Map showing location of vacant public lands.

Without going into details, it is sufficient to state that the rectangular system of subdivision of the public lands, while one of the most beneficial measures leading to the settlement of the Ohio and Mississippi valleys, has been detrimental to the best growth of the western two-fifths of the United States. This has arisen from lack of knowledge by the public, who are the owners, as to the part which irrigation plays in the utilization of the lands of the West. Attention has been concentrated upon land titles, and great care has been exercised in surveying, in the marking of boundaries, and in recording the patents or deeds, while the water, which alone gives value to the land, has scarcely been considered, and the rights to its use are in a most chaotic condition. It would have been far better, if one or the other must be neglected, to give first thought to the water rights and secondary consideration to the titles.

To remedy this evil, so that the remaining public lands will furnish the greatest possible number of homes, is an object worthy the sustained effort of enlightened and patriotic citizens. To assemble the facts upon which intelligent action can be based is a task to which the best efforts of aspiring students or investigators may well be directed. These facts pertain, first of all, to the water supply and its limitations, since in a country where arid land is in excess the useful area is limited by the available water. The development of water for irrigation is a matter of concern to all citizens of the United States, since they are the great landowners, and, as such, are, or should be, interested to see that their lands are put to the best uses. It is their duty also to guard these vast tracts, the heritage of their children, and prevent them from falling into the hands of persons who will treat them as a speculative commodity, regardless of the future. It is from the standpoint of the citizen that the subject is considered. Unquestionably it is a duty of the highest citizenship to provide a hundred homes for independent farmers, instead of permitting the land to be occupied as one or two great stock ranches, controlled by nonresidents, and furnishing employment to only a few nomadic herders.

FORESTS.

The higher mountain slopes and mesas, whose abrupt rise forces upward the winds and compels them to deposit moisture, have, as a consequence of the increased precipitation, a covering of trees. In places the trees are scattered, but in many localities they form dense and valuable forests. Within the arid and semiarid portions of the Western States it is estimated that nearly 120,000,000 acres are covered with woodland, the trees, though scattered, having value for firewood, fence posts, rails, and other purposes essential to the success of the pioneer and the farmer. In addition, more than 75,000,000 acres are covered with heavy forests having commercial value as timber. The aggregate area of desert, woodland, and forest is a little more than half the extent of the arid and semiarid regions; the remainder is grazing land. Thus, so far as area is concerned, it is evident that the grazing industry, or the raising of range stock—that is, cattle, horses, sheep, and goats—is, and probably always will be, the great industrial pursuit. So far as values are concerned, however, there is another aspect of the matter.

The open range of the arid region is generally stated to be capable of supporting 1 cow to every 20 or 30 acres. The same land when watered and put in alfalfa will frequently feed 10 cows to every 20 acres, or in orchards at favorable altitudes will support a family of 3, or even 5 persons. The open range may have a value of 50 cents an acre, while under irrigation the selling price may be $50 an acre, and if in orchards $500 an acre. Thus the values of the lands are directly reversed, the grazing land having the greatest extent and the least value and the irrigated land the least extent and the greatest value.

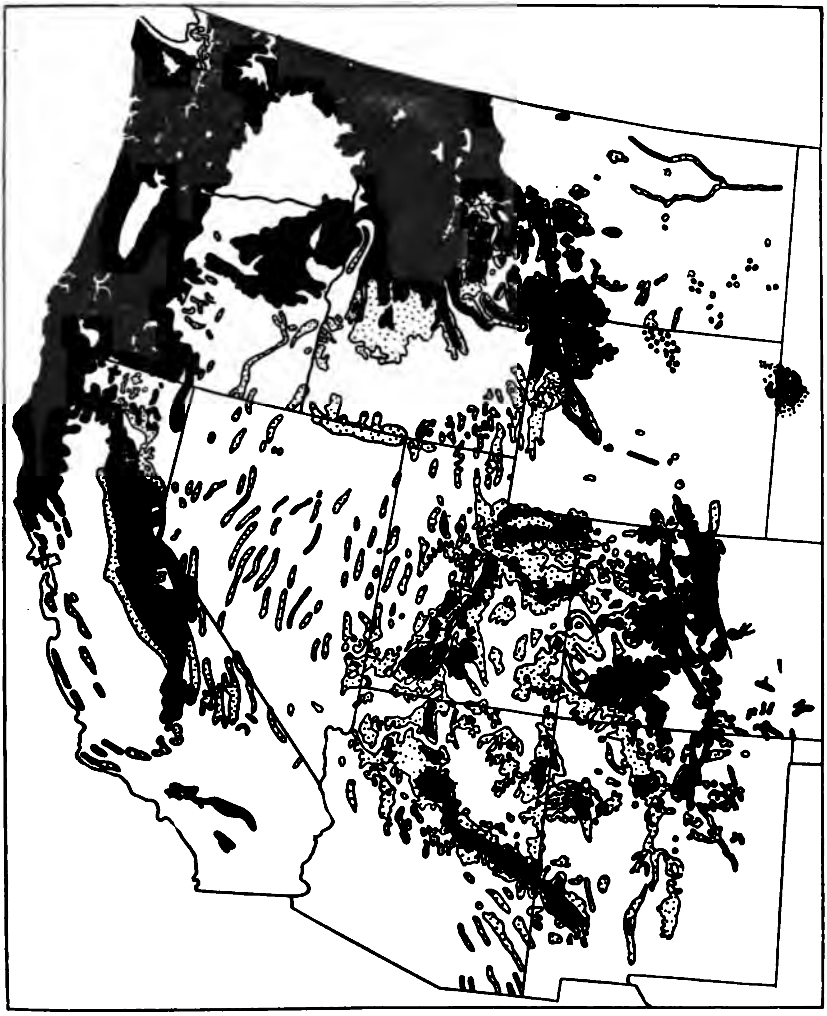


FIG. 4—Map showing location of forests and woodlands of the West. Black portions, forest areas; dotted portions, woodland.

The forests of the arid region mark not only the greatest rainfall but also the localities whence come the principal streams, for the headwaters of nearly all of the rivers and creeks which give value to the lands are within forested regions. It is commonly believed that to a certain extent the forests protect and even regulate the flow of these streams, and it has been urged that the largest and best development of the country requires the conservation of the forests along the headwaters. This conservation can be accomplished by suitable regulations regarding the cutting of the timber. Experience has shown that the removal of the mature or ripe trees, such as are best suited for lumber, improves the general condition of the forest. In some of the wooded areas of the West the proportion of trees which have passed maturity and are dying or dead is as high as 40 per cent. It is obvious that these trees should be removed as quickly as possible before they have lost their value as lumber and become a source of danger to the younger growth. From the commercial standpoint trees have first value for lumber; and, fortunately, the best use of the forest as lumber is not antagonistic to their preservation and to the perpetuation of favorable conditions for a permanent water supply. Public sentiment has been aroused to such an extent that steps have already been taken to preserve the forests of the headwater streams of the West, primarily for the beneficial influence which the leafy cover may have upon stream flow. The Government has already set aside more than 60,000,000 acres of forests and adjacent woodlands, and efforts are being made to preserve the remainder of the large public forests. The first step in the preservation of the forests is to protect them from their great enemy, fire; the next step is the judicious cutting of the mature trees, which should be conducted on a business-like basis that will make the forests yield a revenue sufficient to pay the cost of patrolling and protecting them. It is believed that with systematic supervision, similar to that employed in the preservation of the public forests in other parts of the world, it will be possible to protect the headwaters of the streams without cost to the taxpayer.

The accompanying map, fig. 4, shows the general distribution of the forests of the West, all of which are in the mountains or highlands. The black portions indicate the areas upon which trees of commercial value are growing or have recently grown. The areas surrounded by irregular lines indicate the wooded portions of lower mountains, upon which are scattered trees whose size or condition is such that they are not suitable for lumber, although they are of great value to the settler and the farmer for cheap fuel and material for fence posts, cabins, corrals, and shelter for cattle. Much of this woodland has been included in forest reserves, and under effective protection the more valuable trees will probably thrive. The forest reserves already created do not by any means embrace all of the public lands covered with valuable timber, but each reserve has been segregated for a specific purpose, usually with reference to the protection of the headwaters of streams used for irrigation.

Three bureaus of the Government are closely identified with the forest reservations. To the General Land Office, Department of the Interior, has been intrusted the guarding and patrolling of the reservations. The survey of the regions within and adjacent to the reserves has been assigned to the Geological Survey, which Bureau is preparing detailed topographic maps showing all elevations of the surface, the streams and their catchment areas, the extent of burns resulting from fires, the amount of cutting, and the location of roads, trails, houses, and cabins. Upon the topographic base thus prepared there are indicated, by appropriate colors, the general character and commercial value of the standing timber. After the mapping of the forest reserves by the Geological Survey come the systematic examination and the preparation of working plans by the Bureau of Forestry of the Department of Agriculture. By an effective protection from fire and by following carefully prepared working plans, it would be possible to enlarge the wooded areas upon the headwaters of streams of the arid West, and to increase the beneficial effect which the forests have upon the flow of the streams upon which the irrigators depend.

GRAZING LANDS.

By far the greater portion of the arid West consists of open grazing lands, which vary in their covering of forage plants from the extremely scanty vegetation of the deserts to the thick turf found within the mountain parks. The broad, sandy deserts are occasionally drenched by a local storm or cloudburst, and at once there springs up a scanty herbage, which, though apparently dry and woody, is nutritious and is eagerly sought by the cattle. The less arid plains support a variety of grasses and small plants or shrubs, which, drying under the intense heat, become in effect naturally cured hay, and although sparsely distributed furnish sustenance for horses, cattle, and sheep.

As summer approaches, and the heat upon the deserts and plains becomes intolerable, the herds and flocks gradually move up into the mountains and find excellent grazing upon the slopes and open spaces within the forested areas. Thus a considerable portion of the lands shown in fig. 4 as wooded and forested areas is also of value for grazing. The interests, however, of the stock herder (more particularly the sheep herder) and of the forester are often at variance, since the stock (more particularly the sheep) browse upon the young herbage and prevent the growth and development of small trees. So great is the destruction that it is often necessary to exclude sheep and cattle from the forests in order that the trees may reproduce themselves under natural conditions. For this reason the extension of forest reserves has frequently been opposed by the sheep and cattle interests, and their administration has been hampered by the demand for free grazing upon the public lands.

Sheep raising is one of the chief pursuits of the arid region, and the profits are notably large, so that from a commercial standpoint it is highly important that the grazing lands be as widely extended as possible, even into forest reserves. Obviously it is not good public policy to prevent the growth of wool valued at $10 to encourage the growth of trees which are not worth $1. It is believed, however, that with a proper system for the preservation and development of the forests, while sheep may be excluded from certain areas, they can, with a minimum amount of injury to the young growth, be permitted to graze in other areas. No general working plan has yet been adopted, but the need of one is great, for there is constant controversy between the irrigators and water users on the one hand, who are concerned in protecting their water supply, and the sheep owners on the other hand, who demand that their flocks shall graze wherever young plants can be found.

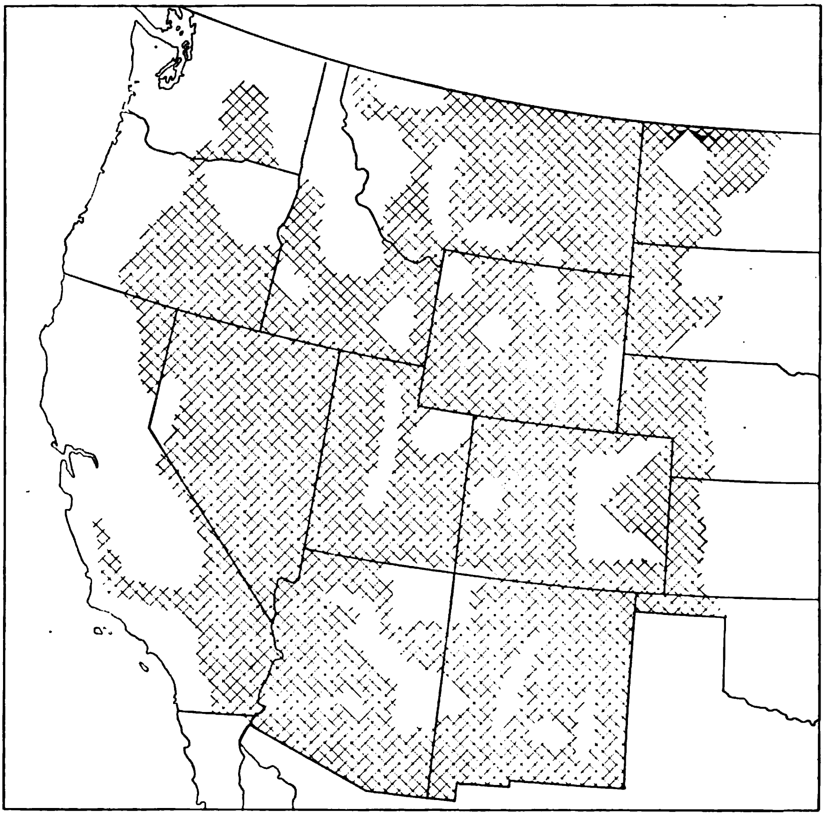


FIG. 5.—Map showing approximate location and extent of open range. Cross-line areas are open range.

The approximate location and extent of the open or free grazing lands are shown on the accompanying map (fig. 5), the cross-lined areas indicating the lands where for the most part sheep, cattle, and horses graze freely. Some of these lands are in private ownership, particularly those in western Nebraska, in Kansas, and in Texas. The map is on too small a scale to exhibit deserts and mountain tops where no forage plants exist. It serves, however, to emphasize the fact that throughout nearly half of the United States grazing is the principal industry, and any plan for the reclamation and utilization of the vast arid region must take cognizance of this fact and be shaped accordingly.

From one standpoint irrigation may be regarded as an outgrowth or later development of the grazing industry, especially in the most northern part of the arid region. In the early days, at the approach of cold weather the sheep and cattle on the open ranges were driven down into the lower valleys, or sought natural shelter. During severe winters the losses were extremely large, occasionally from half to three-fourths of the stock dying during long-continued or extremely stormy weather. With the growth of the business and the overstocking of the ranges, the necessity for providing winter feed for the young and less vigorous animals became evident, and the owners began to irrigate small areas at the home ranches in order to provide forage during the winter.

This practice has increased to such an extent that a balance has been reached between the available summer range and the winter food supply raised by irrigation. In other words, a cattle owner can maintain as many animals as he can feed for two or three months with forage raised by irrigation, providing he can obtain sufficient summer range. If, however, his summer range is limited, or is partly injured by incursions of sheep, he may find it economical to reduce the amount of feed raised by artificial watering, and consequently the size of his herd.

Owing to the competition for summer range and the necessity for providing an increased amount of winter feed, the tendency in the stock-raising business is toward an increase in the number of small owners and a diminution of great herds and flocks. Thus there is a general evolution from stock raising toward what is sometimes known as stock farming. That is to say, the owner of a relatively small herd is tempted to put his irrigated land into crops other than forage, or to raise an additional amount of the latter for sale in local markets. In some of the stock-raising districts, therefore, there is a gradual trend toward intensive farming.

Nearly every settler upon the public domain, whether intending ultimately to raise the ordinary farm crops and fruits or to confine himself to stock raising, requires for a time a certain amount of grazing land, for in any case he must have a few draft animals and dairy cows, and as a rule he finds it profitable to own a small herd of cattle or a band of sheep; therefore he desires and needs the use of the public land in his vicinity in order that he may herd his cattle near by and bring them in at frequent intervals. But under existing laws the settler who is making a home has no legal right to the use of public lands, other than the right possessed in common by every citizen of the country. Often he feels the gross injustice of the laws when cattle or sheep belonging to a nonresident person or corporation come upon the land in his vicinity and destroy all of the nutritious vegetation. Naturally he feels that since he is trying to make a home and is paying taxes for the maintenance of law and order he has a superior right to the use of unoccupied land until it is wanted for homes for other settlers, or until he is in position to raise by irrigation sufficient feed for his cattle. Thus it happens that the settler is often at war with the stock owner; and, in addition, many areas which might have been utilized for homes have been kept vacant from fear of depredations by the cattlemen, or of resort to open violence.

On the free range there is also controversy between rival stock owners, particularly between the sheep herders and the cattlemen. Sheep and cattle can not graze on the same area, and as a rule a band of sheep will render the range unfit for cattle and will drive them out. With the growth of the wool industry the range devoted to cattle is being encroached upon and many of the owners are disposing of their herds and going into the sheep business, finding it possible to make a living upon the public lands by sheep grazing when they can not do so by raising cattle.

The most complete development of the arid region is dependent upon the enactment and enforcement of wise laws regarding grazing upon the public domain. The settlement of a considerable part of the country is dependent upon the ability of the small landowners to utilize the grazing of the adjoining public lands. Without this grazing to supplement the products of the irrigated lands many of these men can not secure a living. This is particularly the case where the irrigable areas are at a distance from market. There the products of the irrigated lands must largely be of the nature of forage, and this to be of value must be consumed by cattle or sheep which find a considerable part of their sustenance on the open public range. This is notably the case during the early stages of settlement, before irrigation has been completely developed. If the newcomer is able to find grazing for his animals during the first few years, he can establish himself upon a comparatively small acreage. If, however, by overgrazing there are no grasses left for his small herd, or if the range is controlled by others, he can not gain a foothold, and may not be able to tide over the first few years.

The prosperity of many of the farmers throughout the West is also closely connected with the success of the cattle industry. Much of the land which may be reclaimed by the Government will derive its value largely from the ability to produce hay, and this in turn is of more or less importance according to the opportunities for cattle feeding. If the summer ranges are maintained in good condition and are occupied by as many cattle as can find sustenance and these cattle belong to various owners, there will be a large demand for hay during the winter months, and this demand will in turn react upon the value of the irrigated land and the prosperity of the owners of it.

Hence any act which tends to restrict or monopolize grazing has an immediate influence upon the farmers on the irrigated tracts.

IRRIGABLE LANDS.

The forests and grazing lands comprise by far the greater part of the arid public domain. Lands which are actually irrigable are relatively small in extent, although first in importance. In most of the States the area now irrigated is less than 1 per cent of the land surface. Under the most complete system of irrigation possible it is probable that not over 5 per cent of the arable land can be irrigated in any one of the Western States. These tracts which have been irrigated, or may be in the future, are widely scattered, their location being dependent not so much upon the character of the soil as upon the opportunity of securing a water supply. The accompanying map (fig. 6) shows the relative positions of the irrigated and irrigable lands, and serves to show that these are not confined to any one part of the West, but are fairly well distributed throughout the entire area. This adds to the difficulty of reclamation, since the wide spaces separating the various projects add to the cost and time necessary for thorough investigation.

This map brings out clearly the fact that the reclamation of the arid West by irrigation is by no means an untried experiment. The work has already been begun and carried to a certain degree of completion by private or corporate capital. At the time of the passage of the reclamation law over 7,500,000 acres were already under irrigation. The total area irrigated in each State is illustrated by fig. 7. In this the black squares in the Western States illustrate by their size the relative amount of land irrigated in the different States, and its proportion to the entire area of the State. Irrigation works have been built along nearly every stream, and some works of considerable magnitude have been constructed for the storage of floods and the diversion of rivers. It is not to be supposed, therefore, that the Government is proceeding along wholly unexplored paths.

The question may be asked at this point, Why has it been found desirable for the Government to take up the work of reclamation if private enterprise has already done so much? The answer lies in the fact that, while this is true, the results have not been wholly satisfactory, as far as the largest interests of the country are concerned.

While the development of the choice spots has been accomplished and the easily available waters have been utilized, the larger public interests have not been guarded, and the making of homes has not been carried on to the extent which the wisest statesmanship requires. In smaller projects, especially those cooperative in nature, private enterprise has been successful, but in the larger and more difficult undertakings, it has not been financially successful, and the public lands have not been utilized to the highest good of the people.

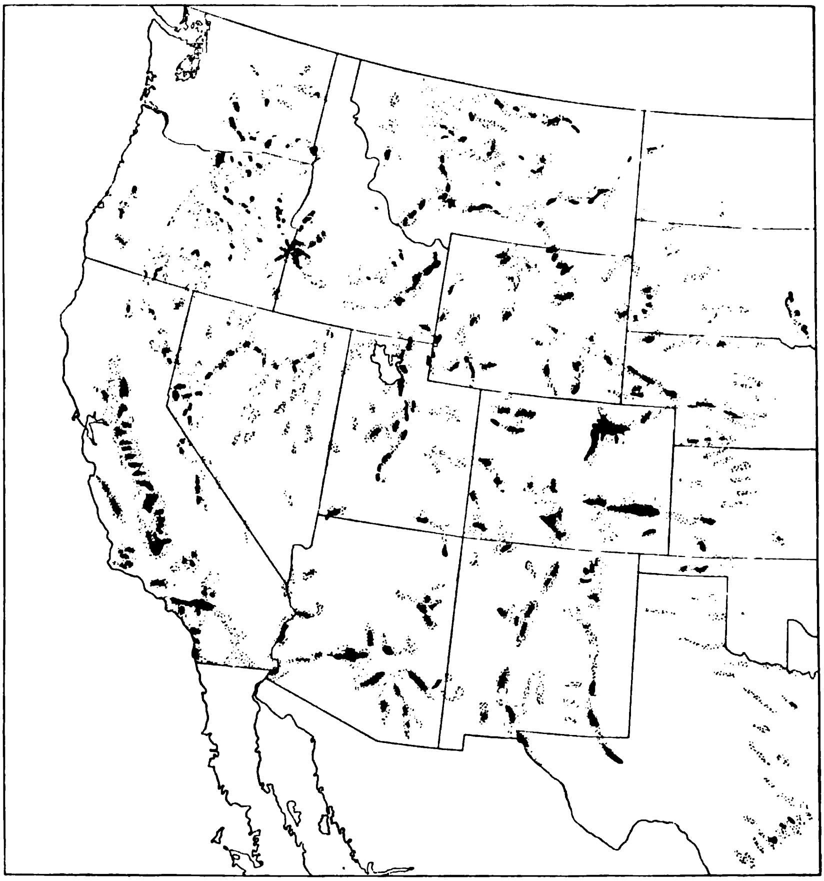


FIG. 6.—Map of the western portion of the United States showing the areas irrigated and irrigable. Black areas show lands that are now irrigated; dotted areas show lands that are irrigable.

The irrigation works already constructed may be divided somewhat arbitrarily into two classes, on the one hand being the small ditches built by individuals or associations, and on the other the larger works constructed as an investment for outside capital and not planned or owned by the irrigators themselves. The works of the first class have, as a rule, been successful. The land-owning irrigators have built and maintained systems of water supply, some of these being consolidated and extended until they are of great magnitude. On the other hand, the works planned on an elaborate scale, built with the use of money borrowed from investors, and intended to sell water rights, have almost without exception been financial failures. Without entering into a discussion of the reasons, it may be said that the whole matter hinges largely upon the principle of cooperation. Wherever men owning land in small tracts have cooperated in constructing and maintaining irrigation systems, they have succeeded. Wherever, on the other hand, they have become tenants or would-be purchasers, there has been general disappointment. The lesson to be drawn is that in future works the principle of cooperation of the landowners should be made a prime requisite. This is emphasized at this place, because in making suggestions for the carrying out of the reclamation law this idea of ultimate control and management by cooperative action will be found to be a dominant factor in the proposed rules and regulations.

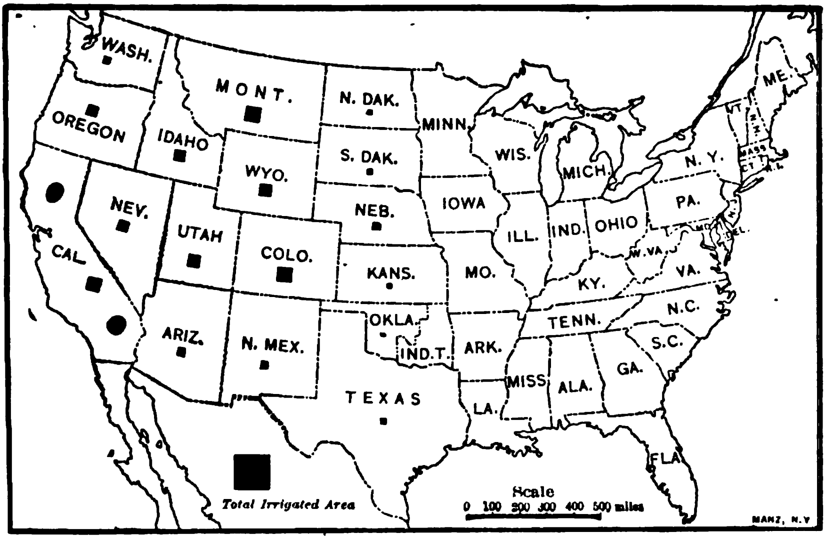


FIG. 7.—Map showing total area irrigated in each State.

HISTORY OF IRRIGATION MOVEMENT.

The passage of the reclamation law, although coming suddenly to the attention of many of the people of the country, was not the result of hasty movement or rapid conclusion. The way for it had been paved through many years of discussion and through many experiments in lawmaking extending over several decades. Various acts of Congress have led up to the present statute, and these have been put to the test, demonstrating their strength or inefficiency, so that the law as it now stands is in large degree the result of evolution, the outcome of trial of various ideas. This evolution has proceeded along the lines, first, of encouraging individual effort and leaving reclamation wholly to private enterprise; next, finding this not sufficient, the attempt was made to interest the various arid States by the terms of what is known as the "Carey law;" finally, the people of the whole country, awaking to the importance of more thorough treatment, urged the passage of the present reclamation law.

For many years there has been a small, rapidly growing body of men who have been convinced that the ultimate solution of the problem of reclamation would be by national treatment. Some of these have advocated this course on the floor of Congress, among them being the late Hon. Abram S. Hewitt, of New York. Of the public men outside of Congress who have devoted some of the best efforts of their lives to the matter may be named, as most conspicuous, Maj. John W. Powell, recently deceased, explorer and scientist. In his study of the geography and geology of the West, Major Powell became impressed with the importance to the country of the arid lands, and urged through public and private writings the careful examination and business-like control of the waters available for irrigation. His publications upon the lands of the arid region have served as an inspiration to many writers, and the ideas set forth in public documents and privately printed articles have been repeated with many modifications by various advocates of the subject.

POWELL IRRIGATION SURVEY.

The preliminary examination of arid public land was carried on by Major Powell under the auspices of the Smithsonian Institution and later under an organization or bureau of the Department of the Interior known as the United States Geographical and Geological Survey of the Rocky Mountain Region. In 1879 this and other surveys maintained by various Departments of the Government were discontinued, and in their place a single bureau, the present United States Geological Survey, was created. The first director was Clarence King, who was succeeded after a few months by John W. Powell, who continued, in connection with other interests, to give particular attention to matters pertaining to the reclamation of the West. Through his personal knowledge and keen appreciation of the importance of the matter the Geological Survey has continued to be connected with problems of water supply and conservation.

The United States Geological Survey is concerned with the water resources of the country primarily through what is known as the organic law contained in the act of Congress of March 3, 1879. To the paragraph creating the office of Director of the Geological Survey the following proviso was attached:

> That this officer shall have the direction of the Geological Survey, and the classification of the public lands and examination of the geological structure, mineral resources, and products of the national domain. And that the Director and members of the Geological Survey shall have no personal or private interests in the lands or

mineral wealth of the region under survey, and shall execute no surveys or examinations for private parties or corporations. (Approved March 3, 1879. Stat. L., vol. 20, p. 394.)

The first requisite in the "classification of the public lands and the examination of the geological structure, mineral resources, and products of the national domain" is a topographic map for guidance and for exhibiting the results. Since the organization of the Survey, therefore, a large part of its energies has been concentrated on the preparation of such a map, showing all elevations by means of contours, also the location of streams, towns, roads, railroads, canals for irrigation or transportation, isolated houses, and boundaries of States, counties, and towns. This map exhibits the drainage areas of streams, the relative elevations of catchment basins and irrigable lands, the topographic features favorable to water conservation, the Land Office lines, the slopes of valleys, and many other details of importance to the development of water powers and of irrigation or the reclamation of the arid lands.

In 1887 the Director of the Geological Survey was called upon by Congress to consider the question of Federal recognition of the irrigation subject. A resolution required the Secretary of the Interior, by means of the Director of the Geological Survey, to make an investigation of that portion of the arid region of the United States where agriculture is carried on by means of irrigation. The law in full, approved March 20, 1888, is to be found on a later page (p. 48).

On October 2, 1888, an appropriation of $100,000 was made for the purpose of carrying out the above-cited law, and particularly for investigating the extent to which the arid regions can be redeemed by irrigation. This was followed by the passage, on March 2, 1889, of a further appropriation of $250,000. A reaction, fostered largely by speculative or grazing interests, set in, and a portion of the law passed October 2, 1888, was repealed by the provisions of the act approved August 30, 1890, no further sums for irrigation works being made available. Under the law, however, the Survey continued to select and map a number of reservoir sites, which have been noted on the records of the General Land Office and described in the annual reports of the Geological Survey. Four volumes of the annual reports were issued, showing the results obtained by what has been designated, for convenience, the Powell Irrigation Survey. The first annual report was published as Part II of the Tenth Annual Report of the Geological Survey, the second as Part II of the Eleventh, the third as Part II of the Twelfth, and the fourth as Part III of the Thirteenth Annual Report of the Geological Survey.

Further investigation of the arid regions and their water supply was carried on in connection with the topographic mapping, the appropriations for this work being continuous. The necessity for a definite appropriation for studying the water resources was, however, recognized, and in 1894 the successor of Major Powell, and the third and present Director of the United States Geological Survey, Mr. Walcott, recommended to and obtained from Congress a specific appropriation of $12,500 for the year ending June 30, 1895.

HYDROGRAPHIC SURVEYS.

Under the various laws which have been noted, and which are given in full on later pages (pp. 48–50), systematic measurements of the streams of the arid region were begun by the Division of Hydrography and were continued as incidental to topographic surveys and selection of reservoir sites. By act of August 18, 1894, the following specific appropriation was made for this class of work:

> For gauging the streams and determining the water supply of the United States, including the investigations of underground currents and artesian wells in arid and semiarid sections, twelve thousand five hundred dollars. (Stat. L., vol. 28, p. 398.)

A further appropriation by act approved March 2, 1895 (Stat. L., vol. 28, p. 940), made available the sum of $20,000 for the fiscal year 1895–96, and a later act was worded as follows:

> For gauging the streams and determining the water supply of the United States, including the investigation of underground currents and artesian wells in arid and semiarid sections, and the preparation of reports upon the best methods of utilizing the water resources of said sections, fifty thousand dollars. (Approved June 11, 1896. Stat. L., vol. 29, p. 436.)

Provision has been made for printing the reports for popular distribution by the following clause in the act last named:

> *Provided*, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives for distribution. (Approved June 11, 1896. Stat. L., vol. 29, p. 453.)

By joint resolution approved May 16, 1902, the restrictions to 100 pages and 5,000 copies were removed.

The appropriation for the year ending June 30, 1902, $100,000, is similar to the above, with a slight change in the wording, as follows:

> For gauging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells in arid and semiarid sections, and the preparation of reports upon the best methods of utilizing the water resources of said sections, one hundred thousand dollars. (Approved June 6, 1900. Stat. L., vol. 31, p. 617.)

In the appropriation for the year ending June 30, 1903, an increase in amount was made, as well as a change in the wording of the appropriation.

> For gauging the streams and determining the water supply of the United States, and for the investigation of underground currents and artesian wells, and the preparation of reports upon the best methods of utilizing water resources, $200,000. (Approved June 28, 1902. Stat. L., vol. 32, p. 455.)

SENATE COMMITTEE.

Shortly after the organization of the Irrigation Survey, the Senate of the United States, by resolution of February 14, 1889, authorized a select committee of seven Senators, known as the Select Committee on Irrigation and Reclamation of Arid Lands, whose duty it was to consider the subject of irrigation and the best mode of reclaiming the arid lands of the United States. Senators Stewart, Allison, Plumb, Hiscock, Reagan, Gorman, and Jones, of Arkansas, constituted this committee. It held its first meeting at St. Paul, Minn., on August 1, 1889. Sessions were continued at Sioux Falls and Huron, S. Dak.; Jamestown and Bismarck, N. Dak.; Glendive, Miles City, Billings, Bozeman, Helena, Butte, and Missoula, Mont.; North Yakima, Ellensburg, and Walla Walla, Wash.; The Dalles and Baker City, Oreg.; Boise, Idaho; Salt Lake City, Utah; Carson, Nev.; San Francisco, Tulare, Bakersfield, Los Angeles, San Bernardino, Riverside, Santa Ana, and San Diego, Cal.; Yuma, Phœnix, and Tucson, Ariz.; El Paso, Tex.; Santa Fe and Las Cruces, N. Mex.; Pecos and Fort Worth, Tex.; Dodge and Garden, Kans.; Pueblo, Colorado Springs, Denver, Fort Collins, and Greeley, Colo.; Cheyenne, Wyo.; and Ogallala, Nebr., the last being on September 19, 1889, after which meetings were held in the city of Washington. A large amount of testimony was taken, and printed in four volumes, together with a majority and minority report, the latter being signed by Messrs. Reagan, Gorman, and Jones.

Further action on the part of the Senate was confined largely to discussion of the matter and to subsequent amendments offered to appropriation bills.

The most important action looking toward irrigation was that taken by Senator Francis E. Warren in advocacy of appropriations for surveys and construction of storage reservoirs in the river and harbor bill. The act of June 3, 1896, provided for the examination of sites and a report upon the practicability and desirability of constructing reservoirs and other hydraulic works necessary for the storage and utilization of water to prevent floods, overflows, erosion of river banks, and breaks of levees, and to reinforce the flow of streams during drought and low-water season. The examination thus authorized was made by Capt. Hiram M. Chittenden, and the results were printed as Document No. 141 of the House of Representatives, Fifty-fifth Congress, second session. This report, dated November 6, 1897, discussed the reservoirs of the arid region, the construction of dams, the functions of reservoirs, their influence in flood prevention, etc., and recommended that the Government should acquire full title and jurisdiction to any reservoir site which it might improve, and full right to the water necessary to fill the reservoir; also that it should build, own, and operate the works, holding the stored waters absolutely free for public use under local regulations.

Following the report of Captain Chittenden, an attempt was made by Senator Warren and his colleagues to secure an appropriation in the river and harbor bill with which to begin this work. The continued agitation of this matter had great influence in the ultimate consideration of the reclamation law.

CENSUS INVESTIGATIONS.

At the time of taking the Eleventh Census, 1889, consideration was given to the importance of obtaining facts concerning the condition of development.

The agricultural enumerators obtained, in addition to the facts concerning farm areas, value and crop statistics and statements as to the area irrigated. From the schedules thus obtained a list of the irrigators was prepared, showing the area of ground irrigated and the principal crops. Circulars of inquiry were sent to these irrigators and a large amount of information was obtained concerning the cost of irrigation and the conditions existing in the localities where agriculture is carried on by artificial watering. The results were compiled and the report prepared by Mr. F. H. Newell, being printed as a separate document.

At the Twelfth Census a similar investigation was undertaken which gave results that could be compared with those obtained ten years previously. Conclusions are given in Volume VI of the Twelfth Census, or Part II of the agricultural volume.

The definite statement of conditions in the different parts of the country and the dissemination of information by the preliminary bulletins of the Eleventh Census undoubtedly had large influence in educating the public to the importance of this subject.

IRRIGATION CONGRESSES.

Popular interest in irrigation was greatly stimulated by the the discussion arising out of the Powell Irrigation Survey and the controversies over the report of the Senate Committee on Irrigation. This led finally to the holding of a series of national irrigation congresses, the prime mover in which was Mr. Wm. E. Smythe, of San Diego, Cal. The first was held in Salt Lake City, Utah, September 15 to 17, 1891. The outcome of discussion at this and several of the subsequent conventions was favorable to the granting in trust, upon such conditions as should serve the public interests, to the States and Territories in need of irrigation, of lands now a part of the public domain within such States and Territories, except mineral lands, for the purpose of developing irrigation.

The second convention of this character was known as the International Irrigation Congress, and was held at Los Angeles, Cal., October 10 to 14, 1893. This congress adopted an address to the people of the United States, dwelling upon the necessity of the reclamation of the arid public domain, stating that the lands are the heritage of the American people, calling attention to the importance of national irrigation, and particularly declaring that all streams rising in one State and flowing through one or more other States must be controlled and equitably divided under Federal authority. It was suggested that a national commission be created to report as soon as possible upon such matters.

The next meeting was known as the Third National Irrigation Congress and was held at Denver, Colo., September 3 to 8, 1894. It passed a number of resolutions, principal among which was one advocating a national irrigation commission vested with the supervision of such irrigation works as might be constructed by the Federal Government.

The fourth congress was held at Albuquerque, N. Mex., September 16 to 19, 1895. It adopted an address to the American people reciting the importance of irrigation and urging the creation of a national irrigation commission to act under the authority of Congress and to make further investigations. It requested the appropriation of $250,000 for the continuation of the irrigation survey as heretofore carried on under the direction of the Department of the Interior.

The Fifth National Irrigation Congress was held at Phœnix, Ariz., December 15 to 17, 1896. It favored the construction of storage reservoirs by the Federal Government where necessary to furnish water for the reclamation and actual settlement of the public lands and also made suggestions for a bill to provide for a public-land commission, as well as various other suggestions and recommendations, among which was a resolution that hydrographic surveys should be made by the Secretary of the Interior and data collected which would be of use in the construction of reservoirs.

The sixth assembly was at Lincoln, Nebr., September 28 to 30, 1897. It indorsed the project for a national commission for the purpose of investigating the existing conditions and submitting to Congress such changes in land laws as might be desirable.

The seventh annual session was held at Cheyenne, Wyo., September 1 to 3, 1898. The hydrographic surveys were indorsed, and it was resolved that Congress be asked to increase the appropriation to $100,000. Reservoir construction was urged, and also leasing of the grazing lands.

The next convention was at Missoula, Mont., September 25 to 27, 1899, where national construction of reservoirs was urged.

The ninth annual session of the National Irrigation Congress was held at Chicago, Ill., November 21 to 24, 1900. At that time the congress was able to view with satisfaction the fact that both of the nation's great political parties had inserted in their platforms declarations in favor of the reclamation of arid America. A memorial was adopted urging preservation of the forests and construction of storage reservoirs. It was held that the work of building the reservoirs necessary to store the floods should be done directly by the Government.

IRRIGATION ASSOCIATION.

It became apparent to the men who habitually attended the annual irrigation congress that a more substantial or permanent organization was needed to carry on continually the work of molding and crystallizing public sentiment. The annual meeting served to arouse enthusiasm, but this did not always result in definite action, and, moreover, the action of one congress might be opposed to that of another, the members of the congress changing with the different localities in which the meetings were held. Accordingly, in 1899, a number of persons who had given much attention to the matter formed an association. Mr. George H. Maxwell, of San Francisco, Cal., became the chairman of the executive committee and the active exponent of its work. The membership of this irrigation association consists largely of business men from both the East and the West, and particularly of those who are interested in the development of the country in such wise that it will afford a home market for Eastern shops and materials. The manufacturing, jobbing, and transporting interests of the country are well represented in the association, and also the labor associations, through their desire to secure additional independent homes for workers.

The irrigation association, from its formation, having considerable funds at its disposal, has been active in disseminating information concerning irrigation, and in securing through correspondence support for the measurements which it has advocated.

PARTY PLATFORMS.

As one the results of the discussion in Congress, in the irrigation meetings, and in the daily press there was aroused a desire on the part of prominent men to be identified with the irrigation movement. This found expression in the platforms of the great political parties in the national campaign of 1900. Following are extracts from these platforms:

REPUBLICAN PLATFORM.

In further pursuance of the constant policy of the Republican party to provide free homes on the public domain, we recommend adequate national legislation to reclaim the arid lands of the United States, reserving control of the distribution of water for irrigation to the respective States and Territories.

DEMOCRATIC PLATFORM.

We favor an intelligent system of improving the arid lands of the West, storing the waters for the purposes of irrigation, and the holding of such lands for actual settlers.

SILVER REPUBLICAN PLATFORM.

We believe the National Government should lend every aid, encouragement, and assistance toward the reclamation of the arid lands of the United States, and to that end we are in favor of a comprehensive survey thereof, and an immediate ascertainment of the water supply available for such reclamation, and we believe it to be the duty of the general government to provide for the construction of storage reservoirs and irrigation works, so that the water supply of the arid region may be utilized to the greatest possible extent in the interests of the people while preserving all rights of the State.

THE PRESIDENT'S MESSAGE.

The efforts of those interested in the West may be said to have found a fitting culmination in the first message of President Roosevelt in December, 1901. The portions of this message which relate to forestry and irrigation have peculiar interest in connection with the reclamation law, since the latter is somewhat general, and the working out of details is left largely to executive action. In considering the possible application of the law, light may be thrown upon the future by weighing carefully the opinions of the Chief Executive, which are as follows:

"Public opinion throughout the United States has moved steadily toward a just appreciation of the value of forests, whether planted or of natural growth. The great part played by them in the creation and maintenance of the national wealth is now more fully realized than ever before.

"Wise forest protection does not mean the withdrawal of forest resources, whether of wood, water, or grass, from contributing their full share to the welfare of the people, but, on the contrary, gives the assurance of larger and more certain supplies. The fundamental idea of forestry is the perpetuation of forests by use. Forest protection is not an end of itself; it is a means to increase and sustain the resources of our country and the industries which depend upon them. The preservation of our forests is an imperative business necessity. We have come to see clearly that whatever destroys the forest, except to make way for agriculture, threatens our well-being.

"The practical usefulness of the national forest reserves to the mining, grazing, irrigation, and other interests of the regions in which the reserves lie has led to a widespread demand by the people of the West for their protection and extension. The forest reserves will inevitably be of still greater use in the future than in the past. Additions should be made to them whenever practicable, and their usefulness should be increased by a thoroughly business-like management.

"At present the protection of the forest reserves rests with the General Land Office, the mapping and description of their timber with the United States Geological Survey, and the preparation of plans for their conservative use with the Bureau of Forestry, which is also charged with the general advancement of practical forestry in the

United States. These various functions should be united in the Bureau of Forestry, to which they properly belong. The present diffusion of responsibility is bad from every standpoint. It prevents that effective cooperation between the Government and the men who utilize the resources of the reserves, without which the interest of both must suffer. The scientific bureaus generally should be put under the Department of Agriculture. The President should have by law the power of transferring lands for use as forest reserves to the Department of Agriculture. He already has such power in the case of lands needed by the Departments of War and the Navy.

"The wise administration of the forest reserves will be not less helpful to the interests which depend on water than to those which depend on wood and grass. The water supply itself depends upon the forest. In the arid region it is water, not land, which measures production. The western half of the United States would sustain a population greater than that of our whole country to-day if the waters that now run to waste were saved and used for irrigation. The forest and water problems are perhaps the most vital internal questions of the United States.

"Certain of the forest reserves should also be made preserves for the wild forest creatures. All of the reserves should be better protected from fire. Many of them need special protection because of the great injury done by live stock, above all by sheep. The increase in deer, elk, and other animals in the Yellowstone Park shows what may be expected when other mountain forests are properly protected by law and properly guarded. Some of these areas have been so denuded of surface vegetation by overgrazing that the ground-breeding birds, including grouse and quail, and many mammals, including deer, have been exterminated or driven away. At the same time, the water-storing capacity of the surface has been decreased or destroyed, thus promoting floods in times of rain and diminishing the flow of streams between rains.

"In cases where natural conditions have been restored for a few years vegetation has again carpeted the ground, birds and deer are coming back, and hundreds of persons, especially from the immediate neighborhood, come each summer to enjoy the privilege of camping. Some at least of the forest reserves should afford perpetual protection to the native fauna and flora, safe havens of refuge to our rapidly diminishing wild animals of the larger kinds, and free camping grounds for the ever-increasing numbers of men and women who have learned to find rest, health, and recreation in the splendid forests and flower-clad meadows of our mountains. The forest reserves should be set apart forever for the use and benefit of our people as a whole and not sacrificed to the short-sighted greed of a few.

"The forests are natural reservoirs. By restraining the streams in flood and replenishing them in drought they make possible the use of waters otherwise wasted. They prevent the soil from washing and so protect the storage reservoirs from filling up with silt. Forest conservation is therefore an essential condition of water conservation.

"The forests alone can not, however, fully regulate and conserve the waters of the arid region. Great storage works are necessary to equalize the flow of streams and to save the flood waters. Their construction has been conclusively shown to be an undertaking too vast for private effort. Nor can it be best accomplished by the individual States acting alone. Far-reaching interstate problems are involved, and the resources of single States would often be inadequate. It is properly a national function, at least in some of its features. It is as right for the National Government to make the streams and rivers of the arid region useful by engineering works for water storage as to make useful the rivers and harbors of the humid region by engineering works of another kind. The storing of the floods in reservoirs at the headwaters of our rivers is but an enlargement of our present policy of river control, under which levees are built on the lower reaches of the same streams.

"The Government should construct and maintain these reservoirs as it does other public works. Where their purpose is to regulate the flow of streams the water should be turned freely into the channels in the dry season to take the same course under the same laws as the natural flow.

"The reclamation of the unsettled arid public lands presents a different problem. Here it is not enough to regulate the flow of streams. The object of the Government is to dispose of the land to settlers who will build homes upon it. To accomplish this object water must be brought within their reach.

"The pioneer settlers on the arid public domain chose their homes along streams from which they could themselves divert the water to reclaim their holdings. Such opportunities are practically gone. There remain, however, vast areas of public land which can be made available for homestead settlement, but only by reservoirs and main-line canals impracticable for private enterprise. These irrigation works should be built by the National Government. The lands reclaimed by them should be reserved by the Government for actual settlers, and the cost of construction should, so far as possible, be repaid by the land reclaimed. The distribution of the water, the division of the streams among irrigators, should be left to the settlers themselves, in conformity with State laws and without interference with those laws or with vested rights. The policy of the National Government should be to aid irrigation in the several States and Territories in such manner as will enable the people in the local communities to help themselves and as will stimulate needed reforms in the State laws and regulations governing irrigation.

"The reclamation and settlement of the arid lands will enrich every portion of our country, just as the settlement of the Ohio and Mississippi valleys brought prosperity to the Atlantic States. The increased demand for manufactured articles will stimulate industrial production, while wider home markets and the trade of Asia will consume the larger food supplies and effectually prevent Western competition with Eastern agriculture. Indeed, the products of irrigation will be consumed chiefly in upbuilding local centers of mining and other industries, which would otherwise not come into existence at all. Our people as a whole will profit, for successful home making is but another name for the upbuilding of the nation.

"The necessary foundation has already been laid for the inauguration of the policy just described. It would be unwise to begin by doing too much, for a great deal will doubtless be learned, both as to what can and what can not be safely attempted, by the early efforts, which must of necessity be partly experimental in character. At the very beginning the Government should make clear, beyond shadow of doubt, its intention to pursue this policy on lines of the broadest public interest. No reservoir or canal should ever be built to satisfy selfish personal or local interests, but only in accordance with the advice of trained experts, after long investigation has shown the locality where all the conditions combine to make the work most needed and fraught with the greatest usefulness to the community as a whole. There should be no extravagance, and the believers in the need of irrigation will most benefit their cause by seeing to it that it is free from the least taint of excessive or reckless expenditure of the public moneys.

"Whatever the nation does for the extension of irrigation should harmonize with and tend to improve the condition of those now living on irrigated land. We are not at the starting point of this development. Over two hundred millions of private capital has already been expended in the construction of irrigation works and many millions acres of arid land reclaimed. A high degree of enterprise and ability has been shown in the work itself, but as much can not be said in reference to the laws relating thereto. The security and value of the homes created depend largely on the stability of titles to water, but the majority of these rest on the uncertain foundation of court decisions rendered in ordinary suits at law. With a few creditable exceptions, the arid States have failed to provide for the certain and just division of streams in times of scarcity. Lax and uncertain laws have made it possible to establish rights to water in excess of actual uses or necessities, and many streams have already passed into private ownership, or a control equivalent to ownership.

"Whoever controls a stream practically controls the land it renders productive, and the doctrine of private ownership of water apart from land can not prevail without causing enduring wrong. The recognition of such ownership, which has been permitted to grow up in the arid regions, should give way to a more enlightened and larger recognition of the rights of the public in the control and disposal of the public water supplies. Laws founded upon conditions obtaining in humid regions, where water is too abundant to justify hoarding it, have no proper application in a dry country.

"In the arid States the only right to water which should be recognized is that of use. In irrigation this right should attach to the land reclaimed and be inseparable therefrom. Granting perpetual water rights to others than users, without compensation to the public, is open to all the objections which apply to giving away perpetual franchises to the public utilities of cities. A few of the Western States have already recognized this and have incorporated in their constitutions the doctrine of perpetual State ownership of water.

"The benefits which have followed the unaided development in the past justify the nation's aid and cooperation in the more difficult and important work yet to be accomplished. Laws so vitally affecting homes as those which control the water supply will only be effective when they have the sanction of the irrigators; reforms can only be final and satisfactory when they come through the enlightenment of the people most concerned. The larger development which national aid insures should, however, awaken in every arid State the determination to make its irrigation system equal in justice and effectiveness that of any country in the civilized world. Nothing could be more unwise than for isolated communities to continue to learn everything experimentally, instead of profiting by what is known elsewhere. We are dealing with a new and momentous question, in the pregnant years while institutions are forming, and what we do will affect not only the present but future generations.

"Our aim should be not simply to reclaim the largest area of land and provide homes for the largest number of people, but to create for this new industry the best possible social and industrial conditions; and this requires that we not only understand the existing situation, but avail ourselves of the best experience of the time in the solution of its problems. A careful study should be made, both by the nation and the States, of the irrigation laws and conditions here and abroad. Ultimately it will probably be necessary for the nation to cooperate with the several arid States in proportion as these States by their legislation and administration show themselves fit to receive it."

LAWS RECOGNIZING IRRIGATION.

Before discussing the reclamation law, reference should be made to the acts of Congress which may be said in one sense to lead up to it, or which have resulted in creating conditions which must be met in putting the reclamation law into effect. Most of these laws appertain to the rights of individuals who have sought to obtain possession of the public lands or of waters flowing across or over them. The most notable exception to this is the so-called Carey Act, which first recognizes the importance of State or Government action in reclaiming the arid land. This law, while not as yet effective in reclaiming any considerable body of land, has served a useful purpose in satisfying some persons who have held that the States should take charge of the matter. The law is given in full on a later page (p. 56), and also a discussion of the conditions resulting from it.

RIGHTS TO USE OF WATER.

The first recognition by Congress of the peculiar conditions of water supply existing in the arid regions is found in section 9 of the act of July 26, 1866 (Stat. L., vol. 14, p. 253), now incorporated in the Revised Statutes of the United States as section 2339. This section was part of a general act relating to mineral lands, the passage of which was due largely to the efforts of Senator Stewart, of Nevada, and resulted from the necessity of providing for an adjustment of the conditions arising from the enormous development of the mining industry, in connection with which the use of water in hydraulic mining had gained great importance, while its use in agriculture by the Mexicans had already attracted some attention. This section of the law, although primarily intended to relate to the rights to water required in mining operations, was very broadly drawn, so as to include agriculture and other uses. It was, as held by the United States Supreme Court, a recognition of the rules and regulations that had grown up in the West, as declared by the local laws, customs, and decisions of the courts. Its language is as follows:

> SEC. 2339. Whenever, by priority of possession, rights to the use of water for mining, agricultural, manufacturing, or other purposes have vested and accrued, and the same are recognized and acknowledged by the local customs, laws, and the decisions of courts, the possessors and owners of such vested rights shall be maintained and protected in the same; and the right of way for the construction of ditches and canals for the purposes herein specified is acknowledged and confirmed; but whenever any person, in the construction of any ditch or canal, injures or damages the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage.

This law was supplemented in July, 1870, by a provision authorizing the reservation of the rights so recognized in all patents issued for the public lands. This additional legislation was originally section 17 of the act of July 9, 1870 (Stat. L., vol. 16, p. 218). It is now section 2340 of the Revised Statutes, as follows:

> SEC. 2340. All patents granted, or preemption or homesteads allowed, shall be subject to any vested and accrued water rights, or rights to ditches and reservoirs used in connection with such water rights, as may have been acquired under or recognized by the preceding section.

DESERT-LAND LAW.

The conditions arising from the aridity of the Western country soon forced themselves upon the attention of Congress, and by act of March 3, 1875 (Stat. L., vol. 18, p. 497), special provision was made for the sale of desert lands in Lassen County, Cal., requiring the entryman to irrigate and reclaim them in somewhat the same manner as under the present desert-land act. It reads as follows:

AN ACT to provide for the sale of desert lands in Lassen County, California.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be lawful for any citizen of the United States, or any person of requisite age who may be entitled to become a citizen, and who has filed his declaration of intention to become such, to file a declaration with the register and the receiver of the proper land district for the county of Lassen, California, in which any desert land is situated, that he intends to reclaim a tract of desert land situated in said county, not exceeding one section, by conducting water upon the same, so as to reclaim all of said land within the period of two years thereafter; and said declaration shall be under oath and shall describe particularly said section of land, if surveyed, and if unsurveyed shall describe the same as nearly as possible without a survey; which said declaration shall be supported by the affidavit of at least two credible witnesses, establishing to the satisfaction of the register or receiver the fact that said lands are of the character described in this act. And at any time within the period of two years after filing said declaration, and upon making satisfactory proof of the reclamation of said tract of land in the manner aforesaid, before the register and the receiver of said land office, such person shall be entitled to enter or locate the reclaimed section, or any part thereof, in the same manner as in cases where public lands of the United States are subject to entry, at a price not exceeding one dollar and twenty-five cents per acre, and shall receive a patent therefor.

SEC. 2. That all lands within said county of Lassen, exclusive of timber lands and of mineral lands, which do not produce grass, or which will not, without such reclamation, produce some agricultural crop, shall be deemed desert lands within the meaning of this act.

This act, which was applicable to only one county of the State of California, paved the way two years later for a general act covering a number of States and Territories in the arid region, which provided for the taking of desert lands by individuals. This is known as "The Desert-Land Act," and was approved March 3, 1877 (Stat. L., vol. 19, p. 377). Its language is as follows:

AN ACT to provide for the sale of desert lands in certain States and Territories.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That it shall be lawful for any citizen of the United States, or any person of requisite age "who may be entitled to become a citizen, and who has filed his declaration to become such," and upon payment of twenty-five cents per acre, to file a declaration under oath with the register and the receiver of the land district in which any desert land is situated, that he intends to reclaim a tract of desert land, not exceeding one section; by conducting water upon the same within the period of three years thereafter, *Provided however* That the right to the use of water by the person so conducting the same, on or to any tract of desert land of six hundred and forty acres shall depend upon bona fide prior appropriation; and such right shall not exceed the amount of water actually appropriated and necessarily used for the purpose of irrigation and reclamation; and all surplus water over and above such actual appropriation and use, together with the water of all lakes, rivers, and other sources of water supply upon the public lands, and not navigable, shall remain and be held free for the appropriation and use of the public for irrigation, mining, and manufacturing purposes subject to existing rights. Said declaration shall describe particularly said section of land if surveyed, and if unsurveyed shall describe the same as nearly as possible without a survey. At any time within the period of three years after filing said declaration, upon making satisfactory proof to the register and receiver of the reclamation of said tract of land in the manner aforesaid, and upon the payment to the receiver of the additional sum of one dollar per acre for a tract of land not exceeding six hundred and forty acres to any one person, a patent for the same shall be issued to him: *Provided*, That no person shall be permitted to enter more than one tract of land, and not to exceed six hundred and forty acres, which sha'l be in compact form.

SEC. 2. That all lands exclusive of timber lands and mineral lands which will not, without irrigation, produce some agricultural crop, shall be deemed desert lands within the meaning of this act, which fact shall be ascertained by proof of two or more credible witnesses under oath, whose affidavits shall be filed in the land-office in which said tract of land may be situated.

SEC. 3. That this act shall only apply to and take effect in the States of California, Oregon, and Nevada, and the Territories of Washington, Idaho, Montana, Utah, Wyoming, Arizona, New Mexico, and Dakota, and the determination of what may be considered desert land shall be subject to the decision and regulation of the Commissioner of the General Land Office.

IRRIGATION INVESTIGATION.

This law requires the irrigation and reclamation of lands by individual effort. The need, however, for action on a larger scale by the General Government was first prominently set before the public by Maj. John W. Powell, formerly Director of the Geological Survey. His report, issued in 1879, dealt largely with the arid region and the problems presented. He recognized clearly and stated definitely that the General Government must of necessity deal directly with the irrigation question. The report was much discussed by those who were interested in the development of the West, and the subject attracted more and more attention from year to year, until after a lapse of ten years a thorough investigation of the water resources of the arid region was authorized by joint resolution of March 20, 1888 (Stat. L., vol. 25, p. 618):

[No. 7.] Joint resolution directing the Secretary of the Interior by means of the Director of the Geological Survey to investigate the practicability of constructing reservoirs for the storage of water in the arid region of the United States, and to report to Congress.

Whereas a large portion of the unoccupied public lands of the United States is located within what is known as the arid region, and now utilized only for grazing purposes, but much of which, by means of irrigation, may be rendered as fertile and productive as any land in the world, capable of supporting a large population, thereby adding to the national wealth and prosperity;

Whereas all the water flowing during the summer months in many of the streams of the Rocky Mountains, upon which chiefly the husbandman of the plains and the mountain valleys chiefly depends for moisture for his crops, has been appropriated and is used for the irrigation of lands contiguous thereto, whereby a comparatively small area has been reclaimed; and

Whereas there are many natural depressions near the sources and along the courses of these streams which may be converted into reservoirs for the storage of the surplus water which during the winter and spring seasons flows through the streams; from which reservoirs the water there stored can be drawn and conducted through properly constructed canals, at the proper season, thus bringing large areas of land into cultivation and making desirable much of the public land for which there is now no demand: Therefore, be it

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior, by means of the Director of the Geological Survey, be, and he is hereby, directed to make an examination of that portion of the arid regions of the United States where agriculture is carried on by means of irrigation, as to the natural advantages for the storage of water for irrigating purposes, with the practicability of constructing reservoirs, together with the capacity of the streams and the cost of construction and capacity of reservoirs, and such other facts as bear on the question of storage of water for irrigating purposes; and that he be further directed to report to Congress as soon as practicable the result of such investigation.

October 2 of the same year an appropriation of $100,000 was made for the purpose of investigating the extent to which the arid region could be redeemed by irrigation. (Stat. L., vol. 25, p. 526.) This act provided also for the segregation of the land needed for sites for reservoirs, ditches, or canals, and enacted in addition that all the lands made susceptible of irrigation by such works should be reserved from sale, and should not thereafter be subject to entry, settlement, or occupation until further provided by law. The language of the act is as follows:

For the purpose of investigating the extent to which the arid region of the United States can be redeemed by irrigation, and the segregation of the irrigable lands in such arid region, and for the selection of sites for reservoirs and other hydraulic works necessary for the storage and utilization of water for irrigation and the prevention of floods and overflows, and to make the necessary maps, including the pay of employees in field and in office, the cost of all instruments, apparatus, and materials, and all other necessary expenses connected therewith, the work to be performed by the Geological Survey, under the direction of the Secretary of the Interior, the sum of one hundred thousand dollars, or so much thereof as may be necessary. And the Director of the Geological Survey, under the supervision of the Secretary of the Interior, shall make a report to Congress on the first Monday in December of each year, showing in detail how the said money has been expended, the amount used for actual survey and engineer work in the field in locating sites for reservoirs, and an itemized account of the expenditure under this appropriation. And all the lands which may hereafter be designated or selected by such United States surveys for sites for reservoirs, ditches, or canals for irrigation purposes and all the lands made susceptible of irrigation by such reservoirs, ditches, or canals are from this time henceforth hereby reserved from sale as the property of the United States, and shall not be subject after the passage of this act to entry, settlement, or occupation until further provided by law: *Provided*, That the President may at any time in his discretion by proclamation open any portion or all of the lands reserved by this provision to settlement under the homestead laws.

In pursuance of this law there was a general withdrawal from entry of all the lands in the arid region. In the next year an appropriation of $250,000 was made for carrying on the work, act of March 2, 1889 (Stat. L., vol. 25, p. 960). This general withdrawal of lands caused objection. Accordingly, in the act of August 30, 1890 (Stat. L., vol. 26, p. 391), the withdrawal from entry of the lands susceptible of irrigation under the act of October 2, 1888, was revoked and appropriation for irrigation surveys was omitted. The work of segregating reservoir sites, however, was maintained. The act contained also a special provision reserving right of way over lands thereafter sold west of the one hundredth meridian for ditches and canals constructed by authority of the United States, thus foreshadowing the present needs of the reclamation service. Such general reservation will be found valuable when, in the development of work under the reclamation act, it is found necessary to extend canals or other irrigation works over lands previously disposed of by the United States. The language of the law is as follows:

> So much of the act of October second, eighteen hundred and eighty-eight, entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and eighty-nine, and for other purposes," as provides for the withdrawal of the public lands from entry, occupation, and settlement is hereby repealed, and all entries made or claims initiated in good faith and valid but for said act shall be recognized and may be perfected in the same manner as if said law had not been enacted, except that reservoir sites heretofore located or selected shall remain segregated and reserved from entry or settlement as provided by said act until otherwise provided by law, and reservoir sites hereafter located or selected on public lands shall in like manner be reserved from the date of the location or selection thereof.
>
> No person who shall, after the passage of this act, enter upon any of the public lands with a view to occupation, entry, or settlement under any of the land laws shall be permitted to acquire title to more than three hundred and twenty acres in the aggregate, under all of said laws, but this limitation shall not operate to curtail the right of any person who has heretofore made entry or settlement on the public lands, or whose occupation, entry, or settlement is validated by this act: *Provided*, That in all patents for lands hereafter taken up under any of the land laws of the United States, or on entries or claims validated by this act, west of the one hundredth meridian, it shall be expressed that there is reserved from the lands in said patent described a right of way thereon for ditches or canals constructed by the authority of the United States.

While this act makes no appropriation for surveys especially related to irrigation, the topographic surveys authorized by the general appropriation for the Geological Survey were of great value in the investigations relating to the irrigation of public lands. The survey and segregation of reservoir sites, as therein provided, has proceeded from time to time, as noted in the various annual reports of the Geological Survey. The authority to continue the examination of the water supply of the arid region still remained as provided by existing laws.

MODIFICATION OF DESERT-LAND LAW.

The subject of individual effort now claimed attention, and by section 2 of the act of March 3, 1891 (Stat. L., vol. 26, p. 1095), the original desert-land law of 1877 was modified in several important particulars, its application being extended to the State of Colorado in addition to the States and Territories named in the original act. The provisions are as follows:

SEC. 2. That an act to provide for the sale of desert lands in certain States and Territories, approved March third, eighteen hundred and seventy-seven, is hereby amended by adding thereto the following sections:

"SEC. 4. That at the time of filing the declaration hereinbefore required the party shall also file a map of said land, which shall exhibit a plan showing the mode of contemplated irrigation, and which plan shall be sufficient to thoroughly irrigate and reclaim said land, and prepare it to raise ordinary agricultural crops, and shall also show the source of the water to be used for irrigation and reclamation. Persons entering or proposing to enter separate sections, or fractional parts of sections, of desert lands may associate together in the construction of canals and ditches for irrigating and acclaiming all of said tracts, and may file a joint map or maps showing their plan of internal improvements.

"SEC. 5. That no lands shall be patented to any person under this act unless he or his assignors shall have expended in the necessary irrigation, reclamation, and cultivation thereof, by means of main canals and branch ditches, and in permanent improvements upon the land, and in the purchase of water rights for the irrigation of the same, at least three dollars per acre of whole tract reclaimed and patented in the manner following: Within one year after making entry for such tract of desert land as aforesaid, the party so entering shall expend not less than one dollar per acre for the purposes aforesaid; and he shall in like manner expend the sum of one dollar per acre during the second and also during the third year thereafter, until the full sum of three dollars per acre is so expended. Said party shall file during each year with the register, proof, by the affidavits of two or more credible witnesses, that the full sum of one dollar per acre has been expended in such necessary improvements during such year, and the manner in which expended, and at the expiration of the third year a map or plan showing the character and extent of such improvement. If any party who has made such application shall fail during any year to file the testimony aforesaid, the lands shall revert to the United States, and the twenty-five cents advanced payment shall be forfeited to the United States, and the entry shall be canceled. Nothing herein contained shall prevent a claimant from making his final entry and receiving his patent at an earlier date than hereinbefore prescribed, provided that he then makes the required proof of reclamation to the aggregate extent of three dollars per acre: *Provided*, That proof be further required of the cultivation of one-eighth of the land.

"SEC. 6. That this act shall not affect any valid rights heretofore accrued under said act of March third, eighteen hundred and seventy-seven, but all bona fide claims heretofore lawfully initiated may be perfected, upon due compliance with the provisions of said act, in the same manner, upon the same terms and conditions, and subject to the same limitations, forfeitures, and contests as if this act had not been passed; or said claims, at the option of the claimant, may be perfected and patented under the provisions of said act, as amended by this act, so far as applicable; and all acts and parts of acts in conflict with this act are hereby repealed.

"SEC. 7. That at any time after filing the declaration, and within the period of four years thereafter, upon making satisfactory proof to the register and the receiver of the reclamation and cultivation of said land to the extent and cost and in the manner aforesaid, and substantially in accordance with the plans herein provided for, and that he or she is a citizen of the United States, and upon payment to the receiver of the additional sum of one dollar per acre for said land, a patent shall issue therefor to the applicant or his assigns; but no person or association of persons shall hold, by assignment or otherwise prior to the issue of patent, more than three hundred and twenty acres of such arid or desert lands; but this section shall not apply to entries made or initiated prior to the approval of this act: *Provided, however*, That additional proofs may be required at any time within the period prescribed by law, and that the claims or entries made under this or any preceding act shall be subject to contest, as provided by the law relating to homestead cases, for illegal inception, abandonment, or failure to comply with the requirements of law, and upon satisfactory proof thereof shall be canceled, and the lands and moneys paid therefor shall be forfeited to the United States.

"SEC. 8. That the provisions of the act to which this is an amendment, and the amendments thereto, shall apply to and be in force in the State of Colorado, as well as the States named in the original act; and no person shall be entitled to make entry of desert land except he be a resident citizen of the State or Territory in which the land sought to be entered is located."

RESERVOIR SITES.

Section 17 of the same act provides that the reservoir sites located and selected under the acts of 1888 and 1890 shall be restricted to the land actually needed for the construction and maintenance of the reservoirs, excluding as far as practicable the land actually occupied by settlers. The section reads as follows:

SEC. 17. That reservoir sites located or selected and to be located and selected under the provisions of "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and eighty-nine, and for other purposes," and amendments thereto, shall be restricted to and shall contain only so much land as is actually necessary for the construction and maintenance of reservoirs; excluding so far as practicable lands occupied by actual settlers at the date of the location of said reservoirs, and that the provisions of "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety-one, and for other purposes," which reads as follows, viz: "No person who shall after the passage of this act enter upon any of the public lands with a view to occupation, entry, or settlement under any of the land laws shall be permitted to acquire title to more than three hundred and twenty acres in the aggregate under all said laws," shall be construed to include in the maximum amount of lands the title to which is permitted to be acquired by one person only agricultural lands and not include lands entered or sought to be entered under mineral land laws.

RIGHTS OF WAY.

In the same act, sections 18 to 21, inclusive, there is a provision under which grants were made to corporations and individuals for right of way for irrigation purposes, in order that they might be assured of such right of way prior to the actual construction, which was a requisite for the vesting of the rights recognized and confirmed by sections 2339 and 2340 of the Revised Statutes, hereinbefore referred to. These sections of the act read as follows:

SEC. 18. That the right of way through the public lands and reservations of the United States is hereby granted to any canal or ditch company formed for the purpose of irrigation and duly organized under the laws of any State or Territory, which shall have filed, or may hereafter file, with the Secretary of the Interior a copy of its articles of incorporation, and due proofs of its organization under the same, to the extent of the ground occupied by the water of the reservoir and of the canal and its laterals, and fifty feet on each side of the marginal limits thereof; also the right to take from the public lands adjacent to the line of the canal or ditch, material, earth and stone, necessary for the construction of such canal or ditch: *Provided*, That no such right of way shall be so located as to interfere with the proper occupation by the Government of any such reservation, and all maps of location shall be subject to the approval of the department of the Government having jurisdiction of such reservation, and the privilege herein granted shall not be construed to interfere with the control of water for irrigation and other purposes under authority of the respective States or Territories.

SEC. 19. That any canal or ditch company desiring to secure the benefits of this act shall, within twelve months after the location of ten miles of its canal, if the same be upon surveyed lands, and, if upon unsurveyed lands, within twelve months after the survey thereof by the United States, file with the register of the land office for the district where such land is located a map of its canal or ditch and reservoir; and upon the approval thereof by the Secretary of the Interior the same shall be noted upon the plats in said office, and thereafter all such lands over which such rights of way shall pass shall be disposed of subject to such right of way. Whenever any person or corporation, in the construction of any canal, ditch, or reservoir, injures or damages the possession of any settler on the public domain, the party committing such injury or damage shall be liable to the party injured for such injury or damage.

SEC. 20. That the provisions of this act shall apply to all canals, ditches, or reservoirs, heretofore or hereafter constructed, whether constructed by corporations, individuals, or association of individuals, on the filing of the certificates and maps herein provided for. If such ditch, canal, or reservoir has been or shall be constructed by any individual or association of individuals, it shall be sufficient for such individual or association of individuals to file with the Secretary of the Interior and with the register of the land office where said land is located a map of the line of such canal, ditch, or reservoir, as in case of a corporation, with the name of the individual owner or owners thereof, together with the articles of association, if any there be. Plats heretofore filed shall have the benefits of this act from the date of their filing as though filed under it: *Provided*, That, if any section of said canal or ditch shall not be completed within five years after the location of said section, the rights herein granted shall be forfeited as to any uncompleted section of said canal, ditch, or reservoir, to the extent that the same is not completed at the date of the forfeiture.

SEC. 21. That nothing in this act shall authorize such canal or ditch company to occupy such right of way, except for the purpose of said canal or ditch, and then only so far as may be necessary for the construction, maintenance, and care of said canal or ditch.

Legislation for canals and reservoirs constructed for commercial purposes by individuals or corporations was passed January 21, 1895 (Stat. L., vol. 28, p. 635), providing for right of way for canals, reservoirs, and tramroads to be used in connection with mining, quarrying, cutting timber, and the manufacturing of lumber, as follows:

AN ACT to permit the use of right of way through the public lands for tramroads, canals, and reservoirs, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of the right of way through the public lands of the United States, not within the limits of any park, forest, military or Indian reservation, for tramroads, canals, or reservoirs to the extent of the ground occupied by the water of the canals and reservoirs and fifty feet on each side of the marginal limits thereof; or fifty feet on each side of the center of the tramroad, by any citizen or any association of citizens of the United States engaged in the business of mining or quarrying or of cutting timber and manufacturing lumber.

An extension of this act is found in the act of May 14, 1896 (Stat. L., vol. 29, p. 120), providing for right of way for electric-power purposes, viz:

AN ACT to amend the act approved March third, eighteen hundred and ninety-one, granting the right of way upon the public lands for reservoir and canal purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the act entitled "An act to permit the use of the right of way through the public lands for tramroads, canals, and reservoirs, and for other purposes," approved January twenty-first, eighteen hundred and ninety-five, be, and the same is hereby, amended by adding thereto the following:

"SEC. 2. That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of right of way to the extent of twenty-five feet, together with the use of necessary ground, not exceeding forty acres, upon the public land and forest reservations of the United States, by any citizen or association of citizens of the United States, for the purposes of generating, manufacturing, or distributing electric power."

By the act of January 13, 1897 (Stat. L., vol. 29, p. 484), provision was made for the occupation of the public lands for reservoirs constructed for the purpose of watering live stock, as follows:

AN ACT providing for the location and purchase of public lands for reservoir sites.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That any person, live-stock company, or transportation corporation engaged in breeding, grazing, driving, or transporting live stock may construct reservoirs upon unoccupied public lands of the United States, not mineral or otherwise reserved, for the purpose of furnishing water to such live stock, and shall have control of such reservoir, under regulations prescribed by the Secretary of the Interior, and the lands upon which the same is constructed, not exceeding one hundred and sixty acres, so long as such reservoir is maintained and water kept therein for such purposes: *Provided,* That such reservoir shall not be fenced and shall be open to the free use of any person desiring to water animals of any kind.

SEC. 2. That any person, live-stock company, or corporation desiring to avail themselves of the provisions of this act shall file a declaratory statement in the United States land office in the district where the land is situated, which statement shall describe the land where such reservoir is to be or has been constructed; shall state what business such corporation is engaged in; specify the capacity of the reservoir in gallons, and whether such company, person, or corporation has filed upon other reservoir sites within the same county; and if so, how many.

SEC. 3. That at any time after the completion of such reservoir or reservoirs which, if not completed at the date of the passage of this act, shall be constructed and completed within two years after filing such declaratory statement, such person, company, or corporation shall have the same accurately surveyed, as hereinafter provided, and shall file in the United States land office in the district in which such reservoir is located a map or plat showing the location of such reservoir, which map or plat shall be transmitted by the register and receiver of said United States land office to the Secretary of the Interior and approved by him, and thereafter such land shall be reserved from sale by the Secretary of the Interior so long as such reservoir is kept in repair and water kept therein.

SEC. 4. That Congress may at any time amend, alter, or repeal this act.

By the act of February 26, 1897 (Stat. L., vol. 29, p. 599), the reservoir sites segregated under the acts of 1888 and 1890, heretofore cited, were rendered subject to applications for right of way under sections 18 to 21 of the act of March 3, 1891, already quoted. The act of 1897 reads as follows:

AN ACT to provide for the use and occupation of reservoir sites reserved.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all reservoir sites reserved or to be reserved shall be open to use and occupation under the right-of-way act of March third, eighteen hundred and ninety-one. And any State is hereby authorized to improve and occupy such reservoir sites to the same extent as an individual or private corporation, under such rules and regulations as the Secretary of the Interior may prescribe: *Provided,* That the charges for water coming in whole or part from reservoir sites used or occupied under the provisions of this act shall always be subject to the control and regulation of the respective States and Territories in which such reservoirs are in whole or part situate.

A paragraph of the forest-reserve act of June 4, 1897 (Stat. L., vol. 30, p. 34), provides as follows concerning the use of waters on such reservations:

All waters on such reservations may be used for domestic, mining, milling, or irrigation purposes, under the laws of the State wherein such forest reservations are situated, or under the laws of the United States and the rules and regulations established thereunder.

On May 11, 1898 (Stat. L., vol. 30, p. 404), the right-of-way acts of 1891 and 1895 were amended for the purpose of extending the application of their provisions, as follows:

AN ACT to amend an act to permit the use of the right of way through public lands for tramroads, canals, and reservoirs, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the act entitled "An act to permit the use of the right of way through the public lands for tramroads, canals, and reservoirs, and for other purposes," approved January twenty-first, eighteen hundred and ninety-five, be, and the same is hereby, amended by adding thereto the following:

"That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of right of way upon the public lands of the United States, not within limits of any park, forest, military, or Indian reservations, for tramways, canals, or reservoirs, to the extent of the ground occupied by the waters of the canals and reservoirs, and fifty feet on each side of the marginal limits thereof, or fifty feet on each side of the center line of the tramroad, by any citizen or association of citizens of the United States, for the purposes of furnishing water for domestic, public, and other beneficial uses.

"SEC. 2. That rights of way for ditches, canals, or reservoirs heretofore or hereafter approved under the provisions of sections eighteen, nineteen, twenty, and twenty-one of the act entitled 'An act to repeal timber-culture laws, and for other purposes,' approved March third, eighteen hundred and ninety-one, may be used for purposes of a public nature; and said rights of way may be used for purposes of water transportation, for domestic purposes, or for the development of power, as subsidiary to the main purpose of irrigation."

On February 15, 1901 (Stat. L., vol. 31, p. 790), a general act was passed providing for the use of the public lands for right of way for reservoirs, ditches, and other methods of conveying water, as follows:

AN ACT relating to rights of way through certain parks, reservations, and other public lands.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the Secretary of the Interior be, and hereby is, authorized and empowered, under general regulations to be fixed by him, to permit the use of rights of way through the public lands, forest, and other reservations of the United States, and the Yosemite, Sequoia, and General Grant national parks, California, for electrical plants, poles, and lines for the generation and distribution of electrical power, and for telephone and telegraph purposes, and for canals, ditches, pipes and pipe lines, flumes, tunnels, or other water conduits, and for water plants, dams, and reservoirs used to promote irrigation or mining or quarrying, or the manufacturing or cutting of timber or lumber, or the supplying of water for domestic, public, or any other beneficial uses to the extent of the ground occupied by such canals, ditches, flumes, tunnels, reservoirs, or other water conduits or water plants, or electrical or other works permitted hereunder, and not to exceed fifty feet on each side of the marginal limits thereof, or not to exceed fifty feet on each side of the center line of such pipes and pipe lines, electrical, telegraph, and telephone lines and poles, by any citizen, association, or corporation of the United States, where it is intended by such to exercise the use permitted hereunder, or any one or more of the purposes herein named: *Provided,* That such permits shall be allowed within or through any of said parks or any forest, military, Indian, or other reservation only upon the approval of the chief officer of the Department under whose supervision such park or reservation falls, and upon a finding by him that the same is not incompatible with the public interest: *Provided further,* That all permits given hereunder for telegraph and telephone purposes shall be subject to the provision of title sixty-five of the Revised Statutes of the United States, and amendments thereto, regulating rights of way for telegraph companies over the public domain: *And provided further,* That any permission given by the Secretary of the Interior under the provisions of this act may be revoked by him or his successor in his discretion, and shall not be held to confer any right, or easement, or interest in, to, or over any public land, reservation, or park.

This act has been held by the Department to supersede the previous acts of 1895, 1896, and section 1 of the act of 1898, except in so far as they relate to tramroad right of way.

CAREY ACT.

On August 18, 1894 (Stat. L., vol. 28, pp. 372–422), Congress passed what is known as the Carey Act, which is section 4 of the act making appropriations for sundry civil expenses of the Government, and is as follows:

SEC. 4. That to aid the public-land States in the reclamation of the desert lands therein, and the settlement, cultivation, and sale thereof in small tracts to actual settlers, the Secretary of the Interior, with the approval of the President, be, and hereby is, authorized and empowered, upon proper application of the State to contract and agree, from time to time, with each of the States in which there may be situated desert lands as defined by the act entitled "An act to provide for the sale of desert land in certain States and Territories," approved March third, eighteen hundred and seventy-seven, and the act amendatory thereof, approved March third, eighteen hundred and ninety-one, binding the United States to donate, grant, and patent to the State free of cost for survey or price such desert lands, not exceeding one million acres in each State, as the State may cause to be irrigated, reclaimed, occupied, and not less than twenty acres of each one hundred and sixty acre tract cultivated by actual settlers, within ten years next after the passage of this act, as thoroughly as is required of citizens who may enter under the said desert-land law.

Before the application of any State is allowed or any contract or agreement is executed or any segregation of any of the land from the public domain is ordered by the Secretary of the Interior, the State shall file a map of the said land proposed to be irrigated which shall exhibit a plan showing the mode of the contemplated irrigation and which plan shall be sufficient to thoroughly irrigate and reclaim said land and to prepare it to raise ordinary agricultural crops, and shall also show the source of the water to be used for irrigation and reclamation, and the Secretary of the Interior may make necessary regulations for the reservation of the lands applied for by the State to date from the date of the filing of the map and plan of irrigation, but such reservation shall be of no force whatever if such map and plan of irrigation shall not be approved. That any State contracting under this section is hereby authorized to make all necessary contracts to cause the said lands to be reclaimed, and to induce their settlement and cultivation in accordance with and subject to the provisions of this section; but the State shall not be authorized to lease any of said lands or to use or dispose of the same in any way whatever except to secure their reclamation, cultivation, and settlement.

As fast as any State may furnish satisfactory proof, according to such rules and regulations as may be prescribed by the Secretary of the Interior, that any of said lands are irrigated, reclaimed, and occupied by actual settlers, patents shall be issued to the State or its assigns for said lands so reclaimed and settled: *Provided*, That said States shall not sell or dispose of more than one hundred and sixty acres of said lands to any one person, and any surplus of money derived by any State from the sale of said lands in excess of the cost of their reclamation shall be held as a trust fund for and be applied to the reclamation of other desert lands in such State.

This act inaugurated the plan of turning over lands to the States for irrigation by any means which they may choose to adopt. The act makes a donation of 1,000,000 acres of desert land to each of the States in the arid region, provided that they shall cause the same to be irrigated and reclaimed. It was amended by the act of June 11, 1896 (Stat. L., vol. 29, p. 434), authorizing the States to create a lien against the lands segregated for the purpose of reclamation, in the following language:

That under any law heretofore or hereafter enacted by any State, providing for the reclamation of arid lands, in pursuance and acceptance of the terms of the grant made in section four of an act entitled "An act making appropriations for the sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety-five," approved August eighteenth, eighteen hundred and ninety-four, a lien or liens is hereby authorized to be created by the State to which such lands are granted and by no other authority whatever, and when created shall be valid on and against the separate legal subdivisions of land reclaimed, for the actual cost and necessary expenses of reclamation and reasonable interest thereon from the date of reclamation until disposed of to actual settlers; and when an ample supply of water is actually furnished in a substantial ditch or canal, or by artesian wells or reservoirs, to reclaim a particular tract or tracts of such lands, then patents shall issue

> for the same to such State without regard to settlement or cultivation: *Provided*, That in no event, in no contingency, and under no circumstances shall the United States be in any manner directly or indirectly liable for any amount of any such lien or liability, in whole or in part.

On March 3, 1901 (Stat. L., vol. 31, p. 1188), Congress extended the terms of this law, which had been limited to ten years from the date of its original passage, so that it should remain in continued operation, allowing ten years for the reclamation of each body of land segregated thereunder. The law reads as follows:

> SEC. 3. That section four of the act of August eighteenth, eighteen hundred and ninety-four, entitled "An act making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety-five, and for other purposes," is hereby amended so that the ten years' period within which any State shall cause the lands applied for under said act to be irrigated and reclaimed, as provided in said section as amended by the act of June eleventh, eighteen hundred and ninety-six, shall begin to run from the date of approval by the Secretary of the Interior of the State's application for the segregation of such lands; and if the State fails within said ten years to cause the whole or any part of the lands so segregated to be so irrigated and reclaimed, the Secretary of the Interior may, in his discretion, continue said segregation for a period of not exceeding five years, or may, in his discretion, restore such lands to the public domain.

The results of the Carey Act during the eight years of its operation are shown by the following table from page 248 of the Report of the Commissicner of the General Land Office for the year 1902, being a statement of the segregations applied for by the various States under the Carey Act, and showing the status of the applications on July 1, 1902.

Statement of segregations applied for under act of August 18, 1894 (28 Stat. L., pp. 372–422), and the acts amendatory thereof, with the action taken thereon, including all lists filed from the passage of the act to July 1, 1902 (areas in acres).

Applications filed and temporarily segregated:		
	Acres.	
Idaho	336,902.88	
Montana	100,001.79	
Nevada	10,402.22	
Oregon	171,993.48	
Utah	236,458.28	
Washington	86,854.26	
Wyoming	246,965.72	
Total		1,189,578.63
Approved and patented:		
Wyoming		11,321.00
Approved, not patented:		
Idaho	301,732.49	
Oregon	8,793.47	
Montana	93,855.00	
Wyoming	165,095.34	
Total		569,476.30

Statement of segregations applied for under act of August 18, 1894, etc.—Continued.

	Acres.	
Relinquished, rejected, and otherwise disposed of:		
Idaho	35, 170. 39	
Montana	2, 472. 51	
Oregon	159, 407. 11	
Utah	236, 458. 28	
Washington	86, 854. 26	
Wyoming	52, 540. 89	
Total		572, 903. 44
Pending before this office:		
Montana	3, 674. 28	
Nevada	10, 402. 22	
Oregon	3, 792. 90	
Wyoming	18, 008. 49	
Total		35, 877. 89
Grand total (approved, disposed of, and pending)		1, 189, 578. 63

It will be observed that in the eight years since the passage of the act applications have been filed for less than 1,200,000 acres by seven of the States out of the maximum of 7,000,000 which these States could have filed upon, while four other States which might have taken advantage of the act have done nothing toward making any filings under it.

Applications for less than 600,000 acres have been presented in such form as to receive the approval of the Department, and of this number only 11,321 acres have been patented, showing that for only this small amount have the proper proofs of reclamation been submitted.

Under the heading "Relinquished, rejected, and otherwise disposed of," amounting to 572,903.44 acres, the Commissioner of the General Land Office states that applications for about 155,000 acres were returned to the States for correction, the remainder, about 417,000 acres, having been relinquished by the States or rejected by the Department.

The Commissioner's report shows that applications for 217,310.36 acres were received during the last fiscal year; so that about 1,000,000 acres of these filings have been under consideration of the Department for a year or more, of which only about 555,000 acres are pending for action. It is understood that a large proportion have been under consideration for several years, the delay being due in many cases to the failure of the State authorities to submit them in such form as to comply with departmental requirements.

From this analysis of the table it appears that no extensive action has been taken in order to obtain the benefits which might be possible under the Carey Act.

During the last year or more very little activity has been displayed in the matter of construction of irrigation works for the reclamation of the lands which have been segregated under this act.

There have been a number of provisions for the investigation of water supply in Indian reservations, and for the construction of irrigation works thereon, to which extended reference is not necessary.

RECLAMATION LAW.

After providing so thoroughly for individual and State effort in the reclamation of arid lands, it became evident that further action was required in order to utilize the large bodies of arid public land which remained unoccupied.

During the twenty-five years in which these various laws for the encouragement of individual and State effort in the reclamation of the arid lands have been in effect the results have been strikingly meager. These laws have been valuable in encouraging the use of water on the public lands and the study of the various problems connected with the proper methods of irrigation. Nearly all the land which is available for irrigation by individual effort or which affords profitable opportunities for comparatively small investments has been utilized, and existing conditions showed the need of adopting other methods to realize the enormous wealth which could be developed by systematic and more effective plans of reclamation. To allow any individual or corporation to obtain the control of the water, as distinct from the ownership of the land, was shown to be unsatisfactory. The Government was not willing to part with its ownership of the lands in the arid region as a whole, or in large compact areas, and without ownership of the lands the construction of expensive irrigation works was found to be in most cases an unsuccessful investment. There was no way open except for the Government itself to undertake the reclamation of its lands. Experience having shown that it is not profitable to invest large amounts in the development and storage of water without the ownership of the lands to be irrigated, it was decided that the owner of the lands, namely the United States, must supply the means. Instead, however, of providing for a specific appropriation from the Treasury for this purpose, Congress decided that the money for the reclamation of the lands should be furnished on condition that it should be returned by those who derived benefit from the expenditure, namely the settlers—in effect, a loan without interest.

Accordingly, by the act approved June 17, 1902 (Stat. L., vol. 32, p. 388), provision was made for the examination, survey, and construction of irrigation works required to reclaim the public lands, and for this purpose there were appropriated the receipts from the sale and disposal of the public lands in the sixteen States and Territories of the arid region, this money constituting what is known as the "reclamation fund." The act provides for the entry of the lands reclaimed in accordance with the provisions of the homestead law, which is modified in certain important particulars, among them the following: That the entryman must repay to the reclamation fund the cost of constructing the works necessary to reclaim the land he has taken; that the entry can not be commuted; and that the area of the entry must be limited to an amount not less than 40 nor more than 160 acres. The law applies to Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming. Its full text is as follows:

AN ACT Appropriating the receipts from the sale and disposal of public lands in certain States and Territories to the construction of irrigation works for the reclamation of arid lands.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That all moneys received from the sale and disposal of public lands in Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming, beginning with the fiscal year ending June thirtieth, nineteen hundred and one, including the surplus of fees and commissions in excess of allowances to registers and receivers, and excepting the five per centum of the proceeds of the sales of public lands in the above States set aside by law for educational and other purposes, shall be, and the same are hereby, reserved, set aside, and appropriated as a special fund in the Treasury to be known as the "reclamation fund," to be used in the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in the said States and Territories, and for the payment of all other expenditures provided for in this Act: *Provided*, That in case the receipts from the sale and disposal of public lands other than those realized from the sale and disposal of lands referred to in this section are insufficient to meet the requirements for the support of agricultural colleges in the several States and Territories, under the Act of August thirtieth, eighteen hundred and ninety, entitled "An Act to apply a portion of the proceeds of the public lands to the more complete endowment and support of the colleges for the benefit of agriculture and the mechanic arts, established under the provisions of an Act of Congress approved July second, eighteen hundred and sixty-two," the deficiency, if any, in the sum necessary for the support of the said colleges shall be provided for from any moneys in the Treasury not otherwise appropriated.

SEC. 2. That the Secretary of the Interior is hereby authorized and directed to make examinations and surveys for, and to locate and construct, as herein provided, irrigation works for the storage, diversion, and development of waters, including artesian wells, and to report to Congress at the beginning of each regular session as to the results of such examinations and surveys, giving estimates of cost of all contemplated works, the quantity and location of the lands which can be irrigated therefrom, and all facts relative to the practicability of each irrigation project; also the cost of works in process of construction as well as of those which have been completed.

SEC. 3. That the Secretary of the Interior shall, before giving the public notice provided for in section four of this Act, withdraw from public entry the lands required for any irrigation works contemplated under the provisions of this Act, and shall restore to public entry any of the lands so withdrawn when, in his judgment, such lands are not required for the purposes of this Act; and the Secretary of the Interior is hereby authorized, at or immediately prior to the time of beginning the surveys for any contemplated irrigation works, to withdraw from entry, except under the homestead laws, any public lands believed to be susceptible of irrigation from said works: *Provided*, That all lands entered and entries made under the homestead laws within areas so withdrawn during such withdrawal shall be subject to all the provisions, limitations, charges, terms, and conditions of this Act; that said surveys shall be prosecuted diligently to completion, and upon the completion thereof, and of the necessary maps, plans, and estimates of cost, the Secretary of the Interior shall determine whether or not said project is practicable and advisable, and if determined to be impracticable or unadvisable he shall thereupon restore said lands to entry; that public lands which it is proposed to irrigate by means of any contemplated works shall be subject to entry only under the provisions of the homestead laws in tracts of not less than forty nor more than one hundred and sixty acres, and shall be subject to the limitations, charges, terms, and conditions herein provided: *Provided*, That the commutation provisions of the homestead laws shall not apply to entries made under this Act.

SEC. 4. That upon the determination by the Secretary of the Interior that any irrigation project is practicable, he may cause to be let contracts for the construction of the same, in such portions or sections as it may be practicable to construct and complete as parts of the whole project, providing the necessary funds for such portions or sections are available in the reclamation fund, and thereupon he shall give public notice of the lands irrigable under such project, and limit of area per entry, which limit shall represent the acreage which, in the opinion of the Secretary, may be reasonably required for the support of a family upon the lands in question; also of the charges which shall be made per acre upon the said entries, and upon lands in private ownership which may be irrigated by the waters of the said irrigation project, and the number of annual installments, not exceeding ten, in which such charges shall be paid and the time when such payments shall commence. The said charges shall be determined with a view of returning to the reclamation fund the estimated cost of construction of the project, and shall be apportioned equitably: *Provided*, That in all construction work eight hours shall constitute a day's work, and no Mongolian labor shall be employed thereon.

SEC. 5. That the entryman upon lands to be irrigated by such works shall, in addition to compliance with the homestead laws, reclaim at least one-half of the total irrigable area of his entry for agricultural purposes, and before receiving patent for the lands covered by his entry shall pay to the Government the charges apportioned against such tract, as provided in section four. No right to the use of water for land in private ownership shall be sold for a tract exceeding one hundred and sixty acres to any one landowner, and no such sale shall be made to any landowner unless he be an actual bona fide resident on such land, or occupant thereof residing in the neighborhood of said land, and no such right shall permanently attach until all payments therefor are made. The annual installments shall be paid to the receiver of the local land office of the district in which the land is situated, and a failure to make any two payments when due shall render the entry subject to cancellation, with the forfeiture of all rights under this Act, as well as of any moneys already paid thereon. All moneys received from the above sources shall be paid into the reclamation fund. Registers and receivers shall be allowed the usual commissions on all moneys paid for lands entered under this Act.

SEC. 6. That the Secretary of the Interior is hereby authorized and directed to use the reclamation fund for the operation and maintenance of all reservoirs and irrigation works constructed under the provisions of this Act: *Provided*, That when the payments required by this Act are made for the major portion of the lands irrigated from the waters of any of the works herein provided for, then the management and operation of such irrigation works shall pass to the owners of the lands irrigated thereby, to be maintained at their expense under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior: *Provided*, That the title to and the management and operation of the reservoirs and the works necessary for their protection and operation shall remain in the Government until otherwise provided by Congress.

SEC. 7. That where in carrying out the provisions of this Act it becomes necessary to acquire any rights or property, the Secretary of the Interior is hereby authorized to acquire the same for the United States by purchase or by condemnation under judicial process, and to pay from the reclamation fund the sums which may be needed for that purpose, and it shall be the duty of the Attorney-General of the United States upon every application of the Secretary of the Interior, under this Act, to cause proceedings to be commenced for condemnation within thirty days from the receipt of the application at the Department of Justice.

SEC. 8. That nothing in this Act shall be construed as affecting or intended to affect or to in any way interfere with the laws of any State or Territory relating to the control, appropriation, use, or distribution of water used in irrigation, or any vested right acquired thereunder, and the Secretary of the Interior, in carrying out the provisions of this Act, shall proceed in conformity with such laws, and nothing herein shall in any way affect any right of any State or of the Federal Government or of any landowner, appropriator, or user of water in, to, or from any interstate stream or the waters thereof: *Provided*, That the right to the use of water acquired under the provisions of this Act shall be appurtenant to the land irrigated, and beneficial use shall be the basis, the measure, and the limit of the right.

SEC. 9. That it is hereby declared to be the duty of the Secretary of the Interior in carrying out the provisions of this Act, so far as the same may be practicable and subject to the existence of feasible irrigation projects, to expend the major portion of the funds arising from the sale of public lands within each State and Territory hereinbefore named for the benefit of arid and semiarid lands within the limits of such State or Territory: *Provided*, That the Secretary may temporarily use such portion of said funds for the benefit of arid or semiarid lands in any particular State or Territory hereinbefore named as he may deem advisable, but when so used the excess shall be restored to the fund as soon as practicable, to the end that ultimately, and in any event, within each ten-year period after the passage of this Act, the expenditures for the benefit of the said States and Territories shall be equalized according to the proportions and subject to the conditions as to practicability and feasibility aforesaid.

SEC. 10. That the Secretary of the Interior is hereby authorized to perform any and all acts and to make such rules and regulations as may be necessary and proper for the purpose of carrying the provisions of this Act into full force and effect.

SCOPE OF RECLAMATION LAW.

As preliminary to a discussion of the reclamation act of June 17, 1902, it would be well to consider the procedure pointed out by its provisions.

The first step is a request from the engineers of the Reclamation Service, made through the head of the organization, the Director of the Geological Survey, to the Secretary of the Interior, for the withdrawal of certain specified lands with a view to their examination in the field, in order to determine the practicability of irrigation works for reclaiming them. When this request is approved by the Secretary of the Interior the proper steps are taken, by the General Land Office, for the withdrawal of the lands through the local land office for the district in which they are located. Thereafter no entries will be allowed, except under the provisions of the homestead law, as modified by the limitations and conditions of the act. In accordance therewith they may be limited to an area as small as 40 acres, and will not be subject to the commutation provisions of the homestead law. The entryman may, therefore, be required to reduce the area of his entry to such limit as in the opinion of the Secretary of the Interior may be reasonably required for the support of a family, and will be called upon to pay the charges per acre which may be determined on in not more than ten annual installments.

As soon as possible after such withdrawal, engineers are instructed to make the survey of the lands and of proposed canals and reservoirs; also to conduct necessary engineering investigations concerning the water supply and the conditions under which the construction will be carried on. Upon the completion of this work the results are to be summarized and submitted to the Secretary of the Interior, with such recommendations as may be deemed advisable by the Director of the Geological Survey, together with maps, plans, and estimates of cost.

It will then be the duty of the Secretary of the Interior to determine whether or not such project is practicable and advisable. If determined to be impracticable or inadvisable, he will restore to the public domain the lands withdrawn, and they will become subject to the public-land laws, as if such withdrawal had never been made. If the project is approved by the Secretary of the Interior, he may cause contracts to be let for the construction of the proposed works, either as a whole or for such portion or section as will constitute a complete system, if it should be deemed best not to undertake the entire project at that time. He will thereupon give public notice of the land which may be reclaimed thereunder, and of the particular limitations contemplated by the law as to area, cost, number of installments, date of payments, etc.

As soon as it shall be possible to furnish water for the irrigation of any particular portion of the lands involved, the entrymen thereon will be allowed to take the water; and as construction progresses additional lands will be supplied from time to time.

When payments have been made in full for the major portion of the lands irrigable under any system, the management and operation of the irrigation works shall pass to the owners of the land irrigated therefrom, to be maintained at their expense, under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior. It is provided, however, that the title to the reservoirs and the works necessary for their protection and operation shall remain in the Government, and that they shall continue under the control and management of the Government unless otherwise provided by Congress. Subject to such management and control as may be necessary under the regulations provided, the direct connection of the Government with the lands irrigated will thereupon cease.

DETAILS OF THE LAW.

In order to carry out the above procedure, the reclamation act provides in detail as follows:

FUNDS FOR RECLAMATION.

Section 1 sets aside for the reclamation fund the moneys received from the sale and disposal of the public lands in sixteen of the States and Territories in the arid and semiarid regions, namely, Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Utah, Washington, and Wyoming. The sums so set aside include also the surplus of the fees and commissions of the registers and receivers in excess of the amounts allowed for their salaries. A deduction is made, however, of 5 per cent of the proceeds of the sale of the public lands, in all of the above States except California and in the Territory of New Mexico, for a fund which had been heretofore set aside by law for educational and other purposes. The moneys so provided for the purposes of the act constitute a special fund in the Treasury, known as the "reclamation fund," and it is to be used in the examination and survey for and the construction and maintenance of irrigation works for the storage, diversion, and development of waters for the reclamation of arid and semiarid lands in the States and Territories named, and for the payment of all other expenditures provided for in the act.

The accumulation of this fund begins with the fiscal year running from July 1, 1900, to June 30, 1901, known officially as the fiscal year 1901. The Treasury Department has furnished a report of the proceeds for the said year for each of the States and Territories named. It is as follows:

Official statement of the reclamation fund, fiscal year 1901.

Arizona	$42, 586. 16
California	205, 030. 40
Colorado	254, 889. 88
Idaho	206, 645. 36
Kansas	20, 188. 78
Montana	367, 342. 31
Nebraska	102, 963. 24
Nevada	9, 183. 47
New Mexico	75, 203. 06
North Dakota	449, 474. 96
Oklahoma	370, 464. 93
Oregon	364, 988. 62
South Dakota	113, 274. 20
Utah	98, 416. 00
Washington	257, 180. 95
Wyoming	206, 989. 59
Total	3, 144, 821. 91

The amount of this fund for the fiscal year ending June 30, 1902, has not yet been determined by the Treasury Department, because the reports relating to the 5 per cent educational fund are not received until near the end of the calendar year. A preliminary statement, which is submitted as an approximation, has been compiled for the year 1902, as follows:

Approximate statement of the reclamation fund, fiscal year 1902.

Arizona	$39,200
California	298,600
Colorado	374,400
Idaho	301,700
Kansas	29,100
Montana	407,400
Nebraska	133,500
Nevada	14,600
New Mexico	72,100
North Dakota	780,600
Oklahoma	640,900
Oregon	547,400
South Dakota	194,500
Utah	48,200
Washington	541,500
Wyoming	176,300
Total	4,600,000

From these two tables it appears that the amount available to July 1, 1902, for the reclamation fund is about $7,744,000. A part of the moneys now set aside for the reclamation fund had been heretofore applied to the support of agricultural colleges in the several States and Territories, in pursuance of an act approved July 2, 1862, and amended August 30, 1890. In order to prevent a deficiency for these purposes, section 1 of the act provides that any deficiency in the sums necessary for the support of said colleges shall be supplied from any moneys in the Treasury not otherwise appropriated.

EXAMINATIONS AND SURVEYS.

The provisions of section 2 comprise a statement of the duties of the Secretary of the Interior under the act. He is authorized and directed to make examination and surveys for appropriate irrigation works, and to locate and construct them. The section provides for the works necessary for the storage, diversion, and development of waters, making special mention of artesian wells. The Secretary is required to report to Congress at the beginning of each regular session the results of such examinations and surveys, with estimates of cost of all contemplated works, the quantity and location of the land irrigated therefrom, and other facts relative to the practicability of each irrigation project. He is required also to report the progress of works in process of construction, as well as those which have been completed.

A brief general description of the several projects examined since the organization of the Reclamation Service in July, 1902, follows; a more detailed report in each case will be found in paragraphs devoted to the State in which the work is located.

The work on the Milk River project in Montana included the investigation of the proposed dam sites at St. Mary Lakes, the examination of canal lines east to the Milk River, and thence to an additional tract of land to be developed in connection therewith, in the vicinity of Malta. A reconnaissance survey was made in the drainage basins of the Yellowstone and Musselshell rivers for the discovery of possible storage sites as a basis of study for the utilization of the waters of those rivers.

In Wyoming examinations have been made of the possibility of storing waters in the Bighorn Mountains for use along their eastern slopes, and at the proposed dam site for the Sweetwater reservoir, on the river of that name, a tributary of the North Platte.

In Colorado work has been prosecuted in the vicinity of Sterling, in connection with the possible utilization of the Pawnee Pass reservoir site, with a view to the irrigation of lands on the north bank of South Platte River. Surveys have also been made by way of examining the proposed plans for diverting the waters of the Gunnison River through a tunnel into the Uncompahgre Valley, where the waters can be applied for irrigation.

The Grand River project, involving the use of the waters of the Grand River on the plains west of Grand Junction in Colorado and Utah, has also been the subject of surveys and examinations.

Parties have been at work in Nevada, in the Truckee-Carson basin, with a view to the utilization of the waters of these rivers and examining the storage possibilities of Lake Tahoe and other lakes in the Sierra Nevada. Investigations have also been made in the valley of the Walker River, Nevada.

In Arizona and California an examination of the Colorado River from the Needles to Yuma has been begun for the study of plans for the reclamation of the low lands along both sides of the river. The practicability of storing the flood waters of the Salt River has also been investigated.

SEGREGATION OF LANDS.

Section 3 covers various operations which are preliminary to the survey of the lands. It authorizes the Secretary of the Interior to withdraw from entry the public lands which may be required for any system of irrigation works, and also the land which may be irrigated from said system. To provide for these two purposes, withdrawals of two characters are authorized. First, for irrigation works (reservoirs, canals, etc.), the lands being withdrawn from entry of any kind. Second, for lands susceptible of irrigation, which remain, however, subject to homestead entries under the conditions specified in the act.

Among these conditions is the limitation of the homestead entry to tracts of not less than 40 nor more than 160 acres. Throughout the greater part of the arid region the consensus of opinion seems to be that 40 acres of good land, with ample water, are sufficient for a homestead. It seems advisable, therefore, at the outset, or until such time as the plans are prepared, to limit the entries to 40 acres. If at that time it is found that the tracts are not taken up in 40-acre entries, it will be possible to increase the size of the homestead without inconvenience. On the other hand, if entries are made of larger extent, it will be found difficult to reduce these to the minimum.

The entries thus made preliminary to the preparation of final plans are subject to all the provisions, limitations, charges, terms, and conditions of the act.

These entries will be subject to the charges necessary to refund the cost of reclamation and also to the other conditions prescribed by the law. An important limitation on these entries is that the usual commutation provisions of the homestead laws are not applicable. This section requires that the survey shall be diligently prosecuted to completion and that the practicability of the project shall be determined by the Secretary of the Interior. In case it should be decided that any project is not feasible, the lands withdrawn are to be restored to entry under the public-land laws.

CONSTRUCTION.

Section 4 provides that the Secretary of the Interior, upon deciding that any project is practicable, may cause contracts to be let for the construction of the same. He is likewise authorized to construct the necessary works in such portion or section as will constitute a complete system in itself. It is provided that no contract shall be entered into unless the necessary funds are available in the reclamation fund.

COST PER ACRE.

After determining upon construction the Secretary of the Interior is required to give public notice of the lands to be irrigated under the project and of the limitation of area per entry which he may deem advisable and which shall be such as may be reasonably required for the support of a family upon the particular lands involved. This notice will also prescribe the charges which are to be made per acre upon the said entries and upon land in private ownership which may be irrigated by the waters supplied from the said works. He will also prescribe at this time the number of annual installments, not exceeding ten, in which such charges shall be paid and the time when the payments shall commence. It is provided that in fixing the charges per acre the sum shall be determined with a view to returning to the reclamation fund the estimated cost of the project, and the same is to be apportioned equitably.

REFUNDING THE COST.

The operation of these provisions will result in making this fund a permanent one, inasmuch as the settlers on these lands and the users of water on lands in private ownership will repay into the fund the cost of constructing the works for the irrigation of their lands. Accordingly the money expended in the construction of any given system will in ten years or less be returned to the reclamation fund and will be available for new construction. Meanwhile the sales of public lands aside from those withdrawn will be added to this fund, so that for a number of years the fund will continue to increase by a sum which will be about the same as the present average annual returns from the sales of lands in these States and Territories. While the reclamation of these lands will tend to diminish the number of homestead entries made in other parts of the public domain, the general stimulation of industry caused by the influx of settlers will have a beneficial effect in increasing the sales of lands for other than agricultural purposes, so that, for some years at least, the increase in the fund should be maintained. By the time a serious diminution becomes apparent, if such decrease should occur, the annual returns from the moneys already invested in reclamation work will furnish a fund for continued operations under this act.

This section provides that the charges on the lands shall be apportioned equitably. This is evidently directed to the considerations that in many cases some of the lands will be less favorably situated for cultivation than others, that the soil in some places will be less capable of raising valuable crops than in others, and that the water supply will be more regular or more abundant in some parts of the reclamation area than in others. These considerations will involve a careful balancing of the possibilities in cultivating the land, and they require a thorough investigation of the location of the lands and a careful study of the various soils found in different parts of the irrigable area reclaimed by each project.

A further provision of section 4 is that in all construction work eight hours shall constitute a day's work, and that no Mongolian labor shall be employed thereon.

Section 5 deals with the requirements of entries made upon these lands. The entryman, in addition to complying with the homestead law, must reclaim for agricultural purposes at least one-half of the total irrigable area of his entry, and pay the charges apportioned against the tract, before receiving a patent for the land. He is required to pay the annual installment to the receiver of the local land office in the district in which the land is situated, and failure to make any two payments when due shall render the entry subject to cancellation, with the forfeiture of all rights under the act, as well as of any moneys paid thereunder.

It is probable that there will not be many cases in which the settler will fail to pay for the cost of reclamation, inasmuch as that charge will be small compared with the actual value of the land with water applied to it. If, however, such failure should occur, it is reasonable to suppose that a contest will be promptly entered against the settler, and that the contestant will, upon obtaining a decision in his favor, and upon the cancellation of the entry, promptly exercise his preference right to enter the same in his own name. In this way the important question of failure to pay installments when due should settle itself with a minimum amount of friction.

RECLAIMING PRIVATE LANDS.

Recognizing the fact that there is scarcely a section of country in the United States, even in the most sparsely settled regions of the West, where an irrigation project would not involve the reclamation of lands in private ownership, as well as those belonging to the United States, this section authorizes the sale of the right to use water for land in private ownership, to be limited, however, to the amount required for a tract not exceeding 160 acres. A further limitation upon this provision is that no such sale shall be made unless the landowner is an actual bona fide resident upon the land, or occupant thereof, residing in the neighborhood. In this case, as in the case of one who takes up public land, the right to the use of water does not permanently attach until all the payments required have been made.

The provisions of this section, that no right to the use of water shall be sold for a tract exceeding 160 acres to any one landowner, would clearly apply to the amounts purchased under different projects. That is to say, the owner of lands irrigated in two or more different projects would be limited, in the total amount of water which he could purchase, by that needed to irrigate 160 acres. This is plainly evident from the further provision in the same sentence of the act—the requirement that the landowner shall be a bona fide resident on the land, or an occupant thereof, residing in the neighborhood. The act accordingly does not contemplate the condition that a man residing in the neighborhood of one tract of land irrigated under the act may acquire water sufficient for 160 acres of land there and later change his residence so as to become qualified to acquire water for another 160 acres under a different project. Therefore the regulations on the subject of acquiring water would very properly include a provision to limit the amount of water sold under this act to that which is needed to irrigate 160 acres of land for any individual, and to exclude application under any additional project after having acquired a right to use water to the extent indicated. The moneys derived from these sales are to be covered into the reclamation fund.

It is apparent that very carefully drawn, stringent regulations must be enforced in order to bring about the obvious intent of the reclamation law. It was asserted by the opponents of the measure during its passage that vast areas of the public lands had already been acquired fraudulently, or by violation of the spirit of the homestead law, and that now the owners of these lands were making an effort to increase the value of the lands by inducing the Government to provide water for them. This is recognized to be a real danger, and many persons who are possessed of areas of land of 1,000 acres or upward have asked, and are evidently seriously considering, how to evade the provisions of the law limiting the area of the water rights to 160 acres. The most obvious method is that similar to the so-called dummy or hobo homestead, in which men make filings, commute payments, and transfer the land at once to a single owner or corporation. This well-proved expedient will doubtless be tried many times in the acquisition of water rights under the reclamation law. It is extremely difficult to distinguish between bona fide and fictitious landowners, but if actual residence and cultivation of the soil is required for a long period, say five years, and total payment and passage of title to the use of the water are not made before the expiration of such period, it is probable that the abuse will be comparatively slight.

The man who is actually living on or near an irrigated tract, and who is earning his subsistence from the soil, can not object to the payments extending throughout a long period—even ten years. A man who is endeavoring to speculate in real estate can not afford, usually, to wait several years for the completion of the title to his right to use the water. The law very plainly is intended to discriminate against such speculation, and to inure to the benefit of the man who is making a permanent home.

OPERATION OF WORKS.

Section 6 provides that the Secretary of the Interior is to use the reclamation fund for the operation and maintenance of the reservoirs and irrigation works constructed under the provisions of the act. When, however, the payments required by the act have been made for the major portion of the lands irrigated therefrom the management and operation of the works are to pass to the owners of the land irrigated thereby, to be maintained at their expense, under such form of organization and under such rules and regulations as may be acceptable to the Secretary of the Interior, except, however, that the title to the reservoirs and the works necessary for their protection and operation shall remain in the Government and that they shall continue under the management of the Government until otherwise provided by Congress.

The particular form of association under which the settlers shall combine when they are required to undertake the operation and maintenance of the irrigation works (except for the reservoirs) can not well be prescribed in detail for all parts of the country. The general principles to govern such associations should be prescribed for the guidance of the settlers, leaving it to them, however, to adopt such rules in regard to the details as may be most in harmony with the conditions of the particular section in which they live and with the customs which prevail. Nothing has as yet been done toward the formulation of such rules, inasmuch as there will be no need for them for some time, and it is desirable that there be opportunity for a careful study of the methods now pursued by the various irrigation associations controlling reservoirs and ditches and the use of water before the Department adopts any special line of procedure for this phase of its work under the act.

In regard to the annual payments to be made by settlers and others using the water from the irrigation works constructed under this act, it would be much more convenient and satisfactory to all concerned if they should be made on behalf of the settlers by associations of the character described in this section of the act. The association, acting as agent for each of its members, could make these collections and pay over the sums to the local land office before the water is furnished, regulating by their own officers the distribution of the water in accordance with the payments made. The results under such a system would be much more satisfactory to the settlers, as well as to the Department, than if special officers should be appointed to represent the Government in this particular work. It will be sufficient if there is a general inspector to supervise the disposition of the water and safeguard the interests of the Government, by keeping in close touch with the work of distributing the water supply.

PURCHASE OF PROPERTY.

In section 7 authority is given to acquire by purchase or condemnation any rights or property that may be needed to carry out the provisions of the act, and to pay from the reclamation fund the sums that may be necessary for that purpose. The power given by this section is extremely important to the successful management of the Reclamation Service. It will enable the Department to avoid the expensive litigation which might frequently arise from the attempts of individuals and corporations to gain possession of controlling points of an irrigation system and demand exorbitant prices for the rights which they might have acquired. This section provides for prompt action by the Attorney-General of the United States when requested to bring suit for condemnation by the Secretary of the Interior. When, therefore, it is found impossible to come to an agreement with the owners of lands or other property needed for the proposed works, the power of eminent domain may be exercised in order to acquire title to such property or rights.

WATER RIGHTS.

Section 8 deals with the question of water rights, and provides that nothing in the act shall be construed as interfering with the laws of any State or Territory relating to water used in irrigation or with the vested rights acquired thereunder, and the Secretary of the Interior is required to proceed in conformity with such laws. Nothing in the act is to affect in any way any right of the Federal Government or of any State or of any landowner, appropriator or user of water in, to, or from any interstate stream or the waters thereof. It is further provided that the right to the use of water acquired under the provisions of the act shall be appurtenant to the lands irrigated, and that beneficial use shall be the basis, the measure, and the limit of the right.

In issuing patent for the lands taken under this act it will be necessary to include therein a conveyance of the water right for the irrigation of the land, and the patent should include, among the clauses conveying this right, an announcement of the above principles, namely, that the water right shall be appurtenant to the lands patented; that beneficial use shall be the basis, the measure, and the limit of the right; and, further, that it shall fail of itself upon violation of the conditions, the extent of the right being always dependent upon the application of the water to beneficial use.

These provisions are of great importance in carrying out the spirit of the act, inasmuch as they will prevent the use, for speculative purposes, of the water rights developed under this law. Moreover, they are an announcement of the fundamental principles of the laws relating to water rights and irrigation as generally administered in the arid region.

APPORTIONMENT OF FUNDS.

Section 9 declares it to be the duty of the Secretary of the Interior to expend the major portion of the funds arising from the sale of public lands within the limits of the State or Territory in which they are collected, subject, however, to the existence of feasible irrigation projects and to his judgment as to whether such action is practicable. It is provided further, however, that when such portion derived from the sale of lands in one State is used in another, the excess shall be restored to the fund as soon as practicable, so that within each ten-year period after the passage of this act the expenditures in each State shall be equalized according to the proportion provided above, subject, however, to the rule of practicability and feasibility, as stated. Fig. 8 shows graphically the derivation of the moneys, by States, for the years 1901 and 1902. In a general way it may be said that the receipts in the various States and Territories are not in proportion to their needs in irrigation construction. Nevada, Arizona, and Utah contain probably the largest proportion of arid area compared with their total extent, and the sales therein produce the smallest amounts for the reclamation fund. The general authority given to the Secretary of the Interior by this section will enable him to consider the needs of the various States without being too closely bound by the proportion in which the sales of lands therein contribute to the reclamation fund, and will thus enable the Department to take up some of the projects most urgently needed in those States without awaiting the collection of sufficient funds to cover the expense of construction. In doing this there can be no reason to doubt that a surplus so expended in a particular State or Territory will be promptly returned to the fund; consequently, at the end of ten years the equalization contemplated by this section will be brought about.

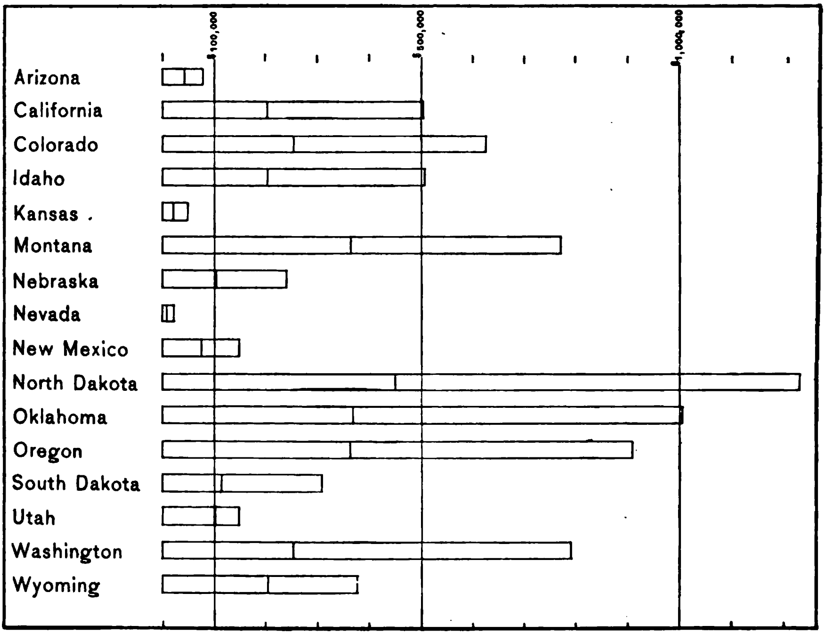


FIG. 8.—Diagram illustrating funds from each State for 1901 and 1902.

The provisions of section 9 divide the reclamation fund into two portions, one designated "the major portion," which is to be expended eventually in the States or Territories in which it originated, subject to the existence therein of feasible irrigation projects; and the other, the minor portion, without such restriction.

"The major portion," which, of course, may be defined as anything more than half, may be regarded as represented by 51 per cent, leaving 49 per cent of the fund without restriction. Thus analyzed into general and special portions, the amount available in the reclamation fund is as follows:

Analysis of reclamation fund for years 1901 and 1902.

	1901, official.	1902, estimated.	Total.	Restricted, 51 per cent.	Unrestricted, 49 per cent.
Arizona	$42,586.16	$39,200	$81,786.16	$41,710.94	$40,075.22
California	205,030.40	298,600	503,630.40	256,851.50	246,778.90
Colorado	254,889.88	374,400	629,289.88	320,937.84	308,352.04
Idaho	206,645.36	301,700	508,345.36	259,256.13	249,089.23
Kansas	20,188.78	29,100	49,288.78	25,137.28	24,151.50
Montana	367,342.31	407,400	774,742.31	395,118.58	379,623.73
Nebraska	102,963.24	133,500	236,463.24	120,596.25	115,866.99
Nevada	9,183.47	14,600	23,783.47	12,129.57	11,653.90
New Mexico	75,203.06	72,100	147,303.06	75,124.56	72,178.50
North Dakota	449,474.96	780,600	1,230,074.96	627,338.23	602,736.73
Oklahoma	370,464.93	640,900	1,011,364.93	515,796.11	495,568.82
Oregon	364,988.62	547,400	912,388.62	465,318.20	447,070.42
South Dakota	113,274.20	194,500	307,774.20	156,964.84	150,809.36
Utah	98,416.00	48,200	146,616.00	74,774.16	71,841.84
Washington	257,180.95	541,500	798,680.95	407,327.28	391,353.67
Wyoming	206,989.59	176,300	383,289.59	195,477.69	187,811.90
Total	3,144,821.91	4,600,000	7,744,821.91	3,949,859.16	3,794,962.75

RULES AND REGULATIONS.

Section 10 gives to the Secretary of the Interior the authority to make the necessary rules and regulations for carrying the provisions of the act into full force and effect. This important power will, it is assumed, be exercised from time to time as subjects for regulation come up for consideration.

ARIZONA.

The reclamation of arid land in this Territory is dependent mainly upon the construction of large storage reservoirs. The irrigable lands are for the most part in the southern half of the Territory and within the drainage basin of Gila River and its principal tributary, Salt River. Irrigation has already been developed to such an extent that there is not sufficient water in ordinary seasons for the lands now under partial cultivation. It is urged by the citizens of the Territory that first attention should be given to providing an adequate supply of water for the small farms whose owners are now suffering for lack of water or who are on the point of moving away because of their inability to cultivate the lands. The situation in this respect, while not peculiar, is most extreme as regards the entire West, the fluctuations of flow of the rivers being most marked and the effect upon the population most disastrous.

The sources from which water may be obtained for reclamation of the arid lands in Arizona are, taken as a whole, the most erratic or irregular in the entire country. There are comparatively few rivers which flow throughout the year. Most of the tributaries of Gila River, beginning in the mountains as perennial streams, lose their waters in the broad, open valleys. From time to time local storms occur, drenching the hillsides or barren plains. The waters from these so-called cloud-bursts rush off in a torrent, following the stream channels for a few hours and then disappearing. They take up and carry with them the loose dust and sand, and, gathering in the stream channels, roll onward the gravels and bowlders, the mass quickly assuming the appearance of a liquid mud.

There is apparently little uniformity of distribution of precipitation, so that it is not possible to depend upon any stream sending down flood waters at a given season of the year. The stream channel may be dry for months, or even years, in succession, and then a number of floods may occur at short intervals. As the various tributaries unite, however, and the drainage basin above a particular point increases in size, the probability of some storm water reaching that point during the year increases, so that while on a small drainage basin a reservoir may not receive water for several years, on a larger basin it may be filled each season.

The extremely erratic occurrence of storms and the difficulty of securing a constant supply renders water storage on a small scale almost impossible in Arizona. The development of the country rests mainly upon the construction of large reservoirs on the main streams, in which floods occur with comparative regularity. It may be advisable at a later time to build small storage reservoirs to supplement the regular supply, arranging these in systems such that if one is not filled for several years, a supply can be obtained from another; or it can be understood that the lands to be supplied with water from such reservoirs are to be devoted to perennial crops of such character that they can be planted when the reservoir is full and not set out in orchards, which require a continual supply of water.

In studying the possibilities of reclamation in Arizona, the most apparent opportunities are those offered by one or another of the large storage basins on Gila River and its tributaries. It is obvious that the future growth of the Territory is dependent upon the best utilization of these. Preliminary work—measuring the river flow and studying the conditions—has been carried on for several years. As a result of this examination there appears to be no way of avoiding the construction of storage dams across the channel of the main river, completely blocking its flow and compelling any excess water to be discharged over or around the dam. This class of structure is most exposed to destruction; and while there is no doubt that such dams can be safely and economically built, yet there is probably no class of engineering which requires greater care, knowledge, and forethought than the building of a large permanent dam across a torrential stream.

In planning a dam of this character every possible fact should be obtained as regards the amount of river flow, the height and duration of floods, the quantity of sediment carried, the character of the foundations, the material to be used, the proper designing of the structure and the wasteways, the strains or stresses which must be met by the completed work, and numerous details as to cements, strength of material, and other items, many of which are but imperfectly understood at present. The average citizen who has not given much thought to the matter is apt to assume that any conventional drawing of a dam can be taken, estimates prepared, and work begun at once. On the contrary, each locality offers its own peculiar problems, such, for example, as faulting or structure of the rocks at the dam site, necessitating a careful selection of the best point, or new and sometimes untried means of cutting off possible leaks around the dam. The material to be used is in each case different from that before employed; its strength must be ascertained, and the best ways of handling and laying it. The distance of the structure from transportation lines may involve the necessity of having cement made on the ground, and this in turn brings in a train of problems which must be satisfactorily solved before work can be begun.

The matter of the accumulation of silt or sediment in the reservoir is in Arizona usually a very important problem, and one upon which facts must be had before final conclusions can be reached.

In making a detailed examination of a reservoir some of the items—such, for example, as the capacity—are easily obtained by means of a direct survey, while others, such as the supply available, can be learned only by long-continued measurements of the stream flowing at this point. By omitting one or another of these items, or giving approximate results, the cost of preliminary surveys can be correspondingly reduced, but the reliability of the conclusions based upon these may be small. For example, in a humid region it may not be necessary to give much consideration to questions of water supply, as from common knowledge it is apparent that there will be ample. On the other hand, in the arid regions it is not safe to make any assumptions. Great care must be given to the measurements, and these must be carried on throughout a period sufficiently long to afford reliable conclusions.

This brief summary of a few of the difficulties to be encountered in reclamation work in Arizona is given not for the purpose of discouraging work, but to emphasize the fact that time and care must be employed, and that although it is vital to some interests to have construction begun at an early date, haste in the matter may result in disaster and in indefinitely delaying steady progress which should be made when work is once begun.

The Twelfth Census of the United States showed that in 1899 there were irrigated 185,396 acres, this being nearly three times the amount irrigated in 1889, which was 65,821 acres. The number of irrigators increased in the same period from 1,075 to 2,981. The greater part of this increase was in Maricopa County, where the number of irrigators doubled.

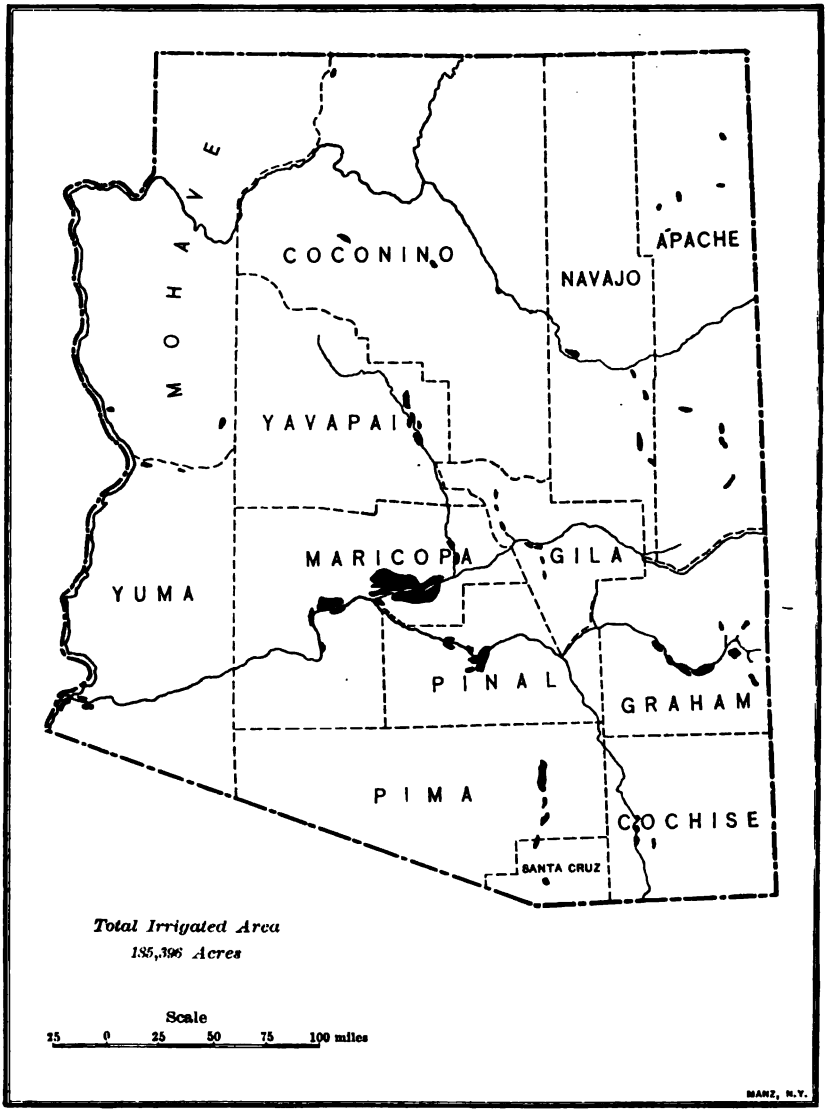


FIG. 9.—Map of irrigated areas in Arizona.

In comparison with the entire area of the Territory—72,268,800 acres—the amount irrigated is almost insignificant, being only about one-third of 1 per cent. The area which in the future may be watered is probably several times that now irrigated, but it is hardly probable that more than 1 or 2 per cent of the entire land surface of the Territory will ever be brought under cultivation by the artificial application of water.

The principal crops irrigated are, in the order of acreage, alfalfa, wheat, barley, and grains cut green for hay. The value of the irrigated crops aggregated $2,250,519, while the estimated cost of construction of the irrigation systems supplying water to the crops was $4,438,352, showing that the value of the irrigated crops in 1899 was very nearly one-half the cost of the works for supplying the water. The average cost per acre for supplying the water is said to be nearly $24, and the average cost of maintenance of the ditches every year was $0.82, while the average value of the irrigated land was found to be $43.50. These averages include all conditions—irrigation systems which might be considered as partial failures but which are in operation, as well as those which are successful. A comparison of the average cost of building the irrigation systems, $24 per acre, and the average value of the irrigated land, $43.50, shows that in this Territory considerable expense may be incurred in building irrigation works, especially if they are well constructed. The areas unappropriated and unreserved in each county on June 30, 1901, are shown in the following table, together with the areas reserved, appropriated, and the total area. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in Arizona on June 30, 1901.

County.	Area unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Apache	1,458,088	4,182,866	1,230,086	6,871,040
Cochise	3,525,586	132,599	275,895	3,934,080
Coconino	5,231,452	6,440,545	694,083	12,366,080
Gila	1,731,766	1,138,426	36,688	2,906,880
Graham	2,870,811	1,010,000	279,189	4,160,000
Maricopa	4,874,077	194,446	573,717	5,642,240
Mohave	8,158,239	384,790	46,411	8,589,440
Navajo	1,810,674	3,465,820	1,012,146	6,288,640
Pima	5,494,610	91,414	445,336	6,031,360
Pinal	2,869,215	295,970	242,175	3,407,360
Santa Cruz	589,046	160,320	26,314	775,680
Yavapai	4,001,995	520,770	509,555	5,032,320
Yuma	5,631,975	267,042	364,663	6,263,680
Total	48,247,534	18,285,008	5,736,258	72,268,800

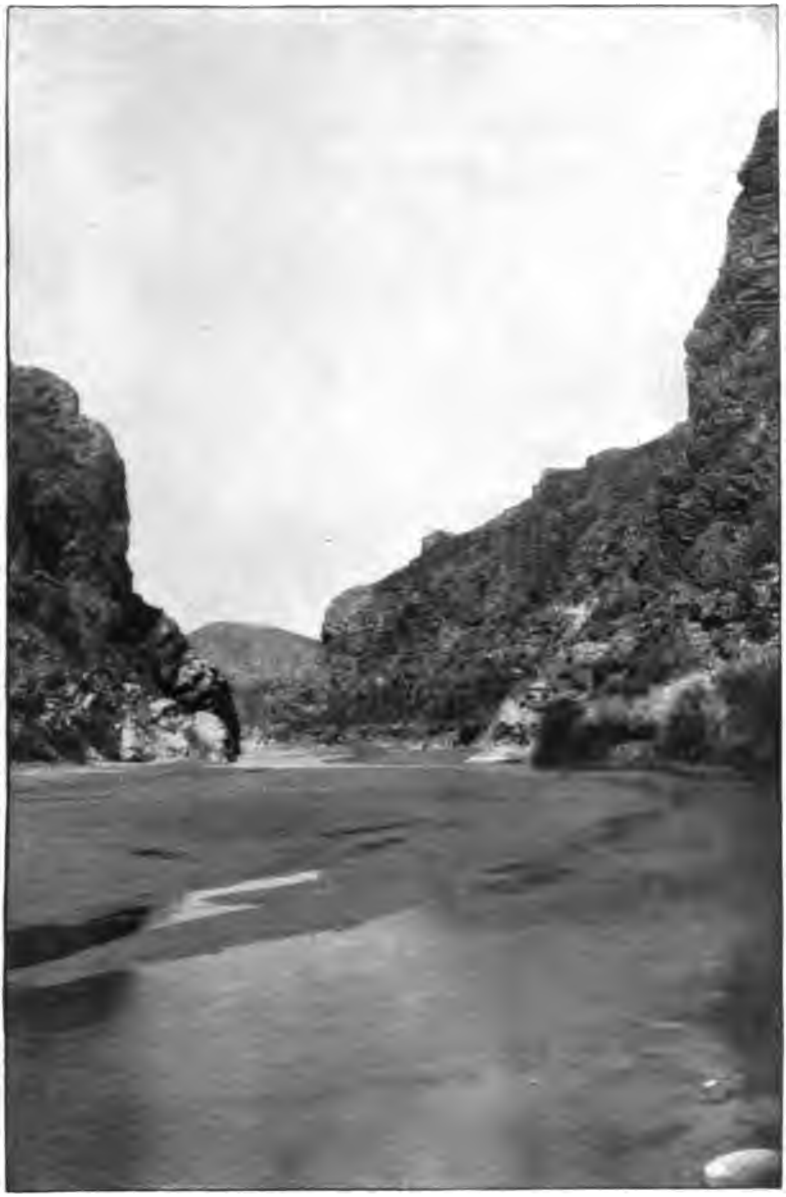
RECLAIMABLE LANDS.

The lands which may be reclaimed in the Territory are widely scattered. If water could be had, nearly one-half of the land surface would be susceptible of cultivation. On account of the scarcity of water, even though all of it were conserved, probably not more than 2 or 3 per cent of the good land could be utilized. It thus becomes necessary to select land primarily with reference to the water supply, but also with reference to the lands already under irrigation. From theoretical considerations it might be best in some respects, in constructing a reclamation system, to keep away from present settlements and take up a locality where there are no claims either to land or to water nor any vested rights to be disturbed. Such conditions, however, do not exist. In almost every locality where there is a small amount of water some of the Government land has been entered and all of the summer flow of the stream utilized. It is necessary, therefore, in any reclamation project to consider the existing complications due to the presence of land in private ownership and to existing water rights.

As above stated, much of the land already partly irrigated needs an additional supply. Canals have been built in excess of the amount of water to be had, and lands have been disposed of in small tracts to settlers, some of whom, not receiving an adequate supply, have left or are on the verge of leaving. It has been urged that as a matter of public necessity as well as of sound business judgment these people should be induced to remain by furnishing them, under the terms of the reclamation law, with enough water to enable them to make a living, especially if at the same time some vacant public land can be thrown open to settlement. How far such a course is justified by the letter and spirit of the law is to be determined by Executive action. There is no question, however, that in Arizona, to a notable extent, the development and utilization of the lands must begin with systems of storing water in localities where it is most needed for lands now in part in the hands of settlers. With the exception of lands along Colorado River, the chief body of reclaimable lands lies in the valleys of Salt and Gila rivers, where private enterprise has already attempted more than could be successfully accomplished under the circumstances. It has been considered advisable, therefore, to study the situation thoroughly, ascertaining the cost of reclamation, and giving special attention to the question whether the people will probably unite and make possible the carrying out of the law through cooperative effort.

Before the passage of the reclamation law, work looking to this end was already under way; examination of the possibility of storing water on Gila River had been begun, with particular reference to a supply for lands in the vicinity of Florence and on the Gila River Indian Reservation, also for storage reservoirs on Salt and Verde rivers for lands near Phœnix.

The conditions of this work and of the investigations made during the year 1902 are given in the following pages.



SAN CARLOS DAM SITE, ARIZONA, LOOKING UPSTREAM.

SAN CARLOS PROJECT.

On both sides of Gila River, in southern Arizona, extending from the junction with Salt River upstream for about 50 miles, is a tract of land which has been set aside as the Gila River Indian Reservation, and upon which have been located over 7,000 Indians, over half of these being Pimas, the remainder Papago, with a few Maricopa. These people have, from time immemorial, cultivated the land in this vicinity by means of water taken from the river. In 1886 the Indian agent called attention to the fact that the construction of irrigation works on the river above would practically destroy the farms of the Indians on the river, and in that year the subject was referred to the Attorney-General to take the necessary steps to protect the Indians from the effect of the projected Florence canal. Later in the year the Director of the Geological Survey was instructed by the Secretary of the Interior to investigate and report upon the situation. As a result of the investigation it was shown that the construction of irrigation works would result injuriously to the Indians. Legal steps were, however, held in abeyance, and the matter was finally allowed to drop. The conditions gradually became worse, and in 1895 the Indian agent made another appeal. In November of that year the Secretary of the Interior again instructed the Director of the Geological Survey to make an examination. Mr. Arthur P. Davis was detailed to the task and was assisted by Mr. Cyrus C. Babb, and consulted with Mr. J. B. Lippincott, of California. The result of this investigation has been printed as Senate Document No. 27, Fifty-fourth Congress, second session.

Mr. Davis at that time suggested the construction of a dam at The Buttes, on Gila River, about 30 miles above the reservation, this being the nearest point at which there seemed to be favorable opportunities for storage. With the funds available for the investigation it was not possible then to make soundings for bed rock to determine the feasibility of constructing a masonry dam. It was recommended that a careful study be made of the situation. Accordingly, the act making provisions for current and contingent expenses in the Indian Department approved July 1, 1898, included an appropriation of $20,000 for ascertaining the depth to bed rock at The Buttes and for ascertaining the feasibility and cost of construction of a dam across the river; also for a report upon what was known as the Queen Creek project, this being for a smaller reservoir on an intermittent stream north of The Buttes site.

Stream measurements were at once begun on Gila River and on Queen Creek, and maintained throughout 1899. Bids were invited for ascertaining the depth to bed rock, but the offers were so excessive in cost that it was determined to put down drill holes by day labor. The work was done at about one-third the cost as estimated from the bids. The maximum depth to bed rock reached by the holes was 122.6 feet. The unexpectedly great depth necessitated an unfavorable report upon the project and attempt was at once made to find a better location. The river was explored above The Buttes and reservoirs were surveyed; one of these was at Riverside, about 15 miles farther up the river; another at San Carlos, about 40 miles above Riverside, and others at different points.

The most favorable conditions for storing water were found on the White Mountain Indian Reservation, a short distance below the San Carlos Indian Agency. Two holes were sunk to bed rock, one reaching it at 23 feet and the other at 74 feet. Further progress was stopped by high water, operations being discontinued on July 31, 1899.

The results of these examinations were published in Water-Supply Paper No. 33, which gives in detail the engineering features and emphasizes the importance of further examination of the San Carlos site and particular study of the silt problem. The large amount of mud carried in suspension by Gila River renders essential a careful consideration of the effect that this will have in filling the reservoir. While it is at present believed that this will not be an insuperable obstacle, the facts must be carefully weighed in considering the feasibility of the enterprise.

Systematic observations of the amount of water available at the San Carlos dam site have been and are being carried on, together with determinations of the amount of material in suspension. The results are shown in the following table:

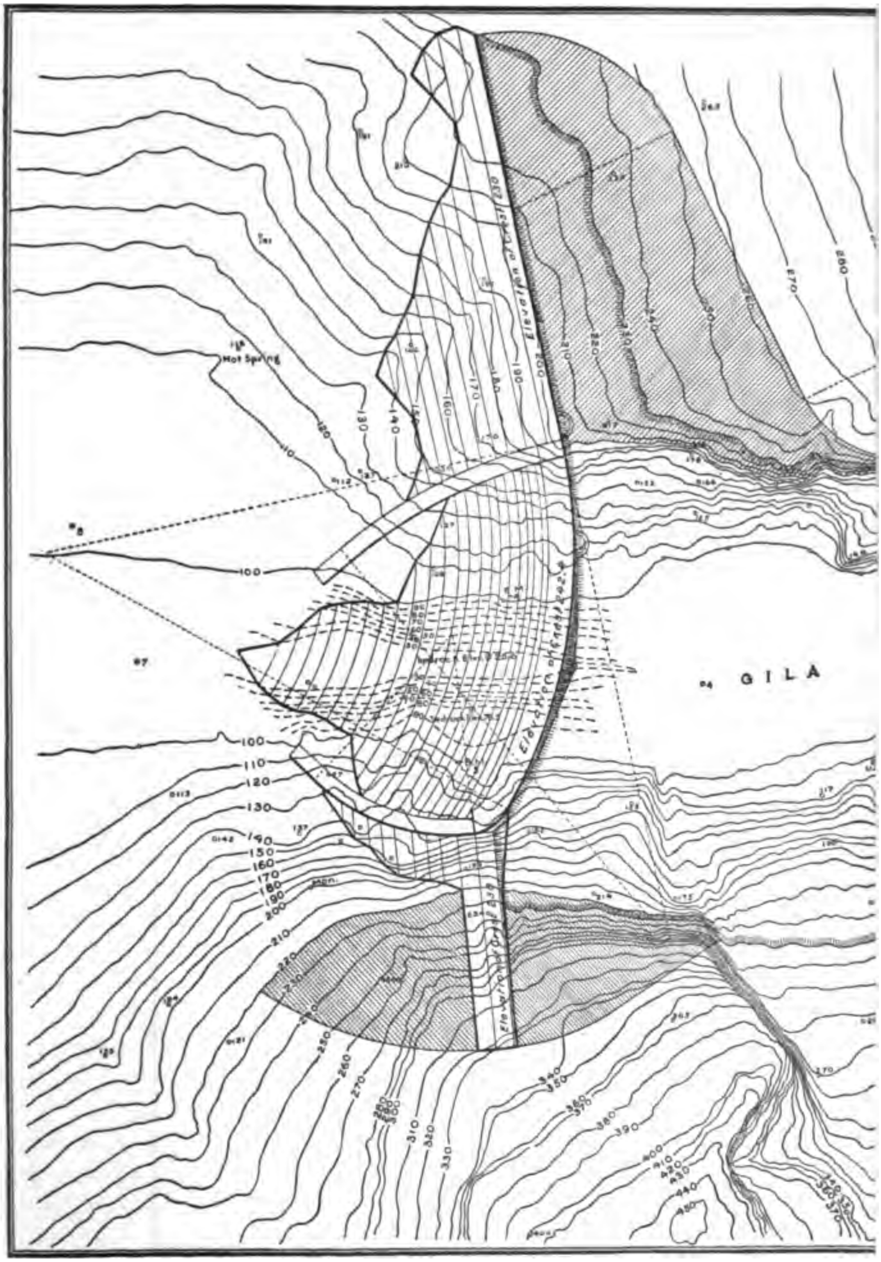
Computations based on sediment observations of Gila River at San Carlos station, San Carlos, Ariz.

[Drainage area, 13,455 square miles.]

Month.	c. c. of water tested during the month.	Sediment.		Percentage of dry material to total amount of water tested.	Run-off in acre-feet for the month.	Total volume of dry material in acre-feet for the month.
		c. c. of wet material.	Grams of dry material.			
1901.						
November 26 to December 31	3,600	....	1.54	.000428	7,916	3.39
1902.						
January[a]	3,100	....	.1135	.0000366	6,119	.22
July	400	39	....	....	....	....
August	3,100	296	83.92	.02707	48,698	1,318.25
September[b]	3,000	86	7.63	.002464	5,821	14.34
December	1,600	62	....	....	....	....
The year	....	....	....	....	....	....

[a] Water clear, February to June.

[b] Water clear in October and November



CONTOUR MAP OF SAN CARLOS DAM SITE

REMOVAL OF SEDIMENT.

Observations at The Buttes reservoir site on Gila River have revealed such high percentages of solid matter as to render the maintenance of a reservoir at that site expensive. Investigation has shown, however, that a large proportion of the silt received by the Gila waters comes from the basin of San Pedro River, which flows through a light, ashy soil almost entirely denuded of timber or other vegetation, and subject to violent cloud-bursts, which carry immense quantities of solid matter into the channel of Gila River, while other portions of the Gila water supply come from the high mountains, heavily covered with timber and other vegetation, from which the streams flow as clear and pure as those in New York or New England. The San Carlos reservoir is located above the San Pedro Basin, and while it intercepts the water supply furnished by the headwaters of the Gila proper - the San Francisco, Eagle Creek, and other streams flowing from the lofty Mogollon Mountains, which furnish very little solid matter to the reservoir—it escapes the silt-laden waters of the San Pedro, which joins the river below.

From these considerations it is believed that less sediment will be encountered in the waters of the Gila at San Carlos than at The Buttes. Observations have been made which confirm this expectation. But the silt problem is recognized as one which must be met, and means must be provided for its solution. There will be no necessity for silt removal until the lapse of fifteen or twenty years after the construction of the dam, when it is probable that the deposit of silt will begin to be felt as an inroad upon the storage capacity of the reservoir. By that time the community developed by the stored waters should be firmly established upon a solid basis and would not be embarrassed by a moderate charge for maintenance.

The plans for combating the deposit of silt and clearing the reservoir are as follows: An outlet tunnel of large capacity is to be provided on a level with the river near the dam, which is at the deepest part of the reservoir. All the water taken from the reservoir can be drawn through this tunnel under full head and will keep the adjacent bottom clear of silt, which will be carried out by the rushing waters. This provision, while it will not remove or prevent the deposit of silt in the rest of the reservoir, is expected to contribute materially to the solution of the problem, as experience at the Sweetwater and other reservoirs shows that the greatest deposits are in the deepest parts of the reservoir—that is, near the dam. The main provision contemplated, however, is the method of ground sluicing familiar in placer-mining regions. Whenever the water in the reservoir is drawn down sufficiently the river will be diverted in temporary ditches and carried along the upper edge of the reservoir. At intervals portions of this water will be turned loose and allowed to rush down the sidehill and will wash with it much of the deposit of fine silt, carrying it through the lower part of the reservoir to the outlet tunnel, the water being diverted below for irrigation. The silt deposits are mainly of fine, light material, soft if damp, and full of cracks if dry. It has been estimated that it can be removed by this method at a cost of from 8 to 9 mills per cubic yard. In case the material is hard or the slope insufficient, the above method may be supplemented by the use of hydraulic monitors working under the head of waters diverted above.

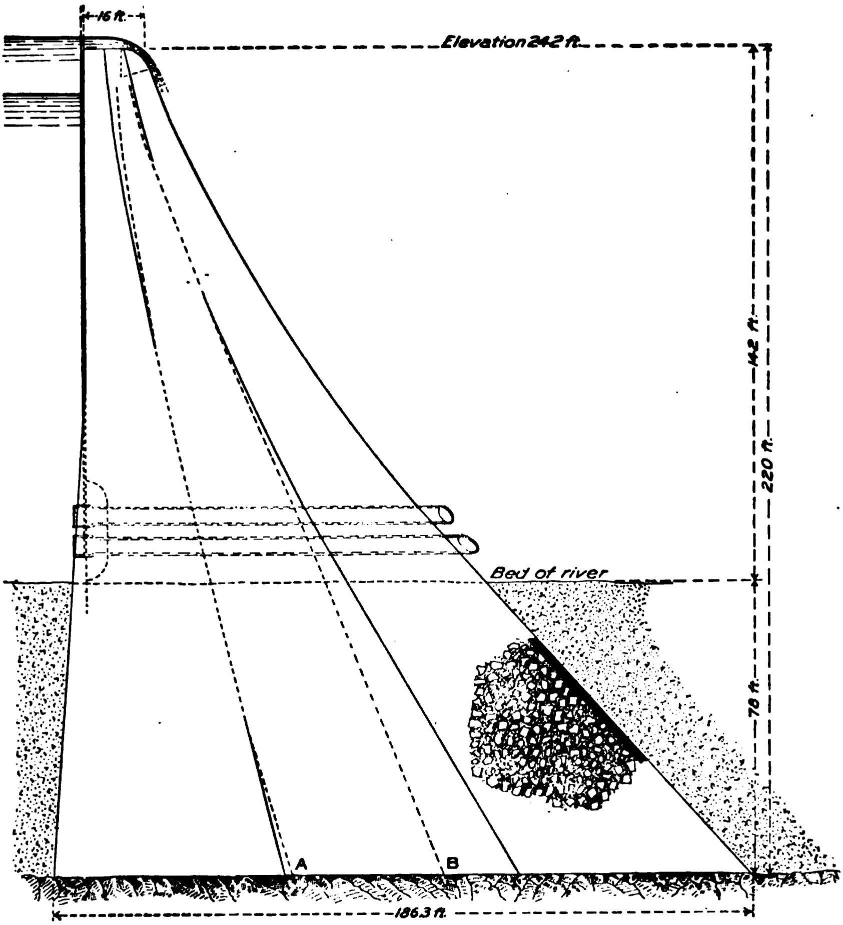
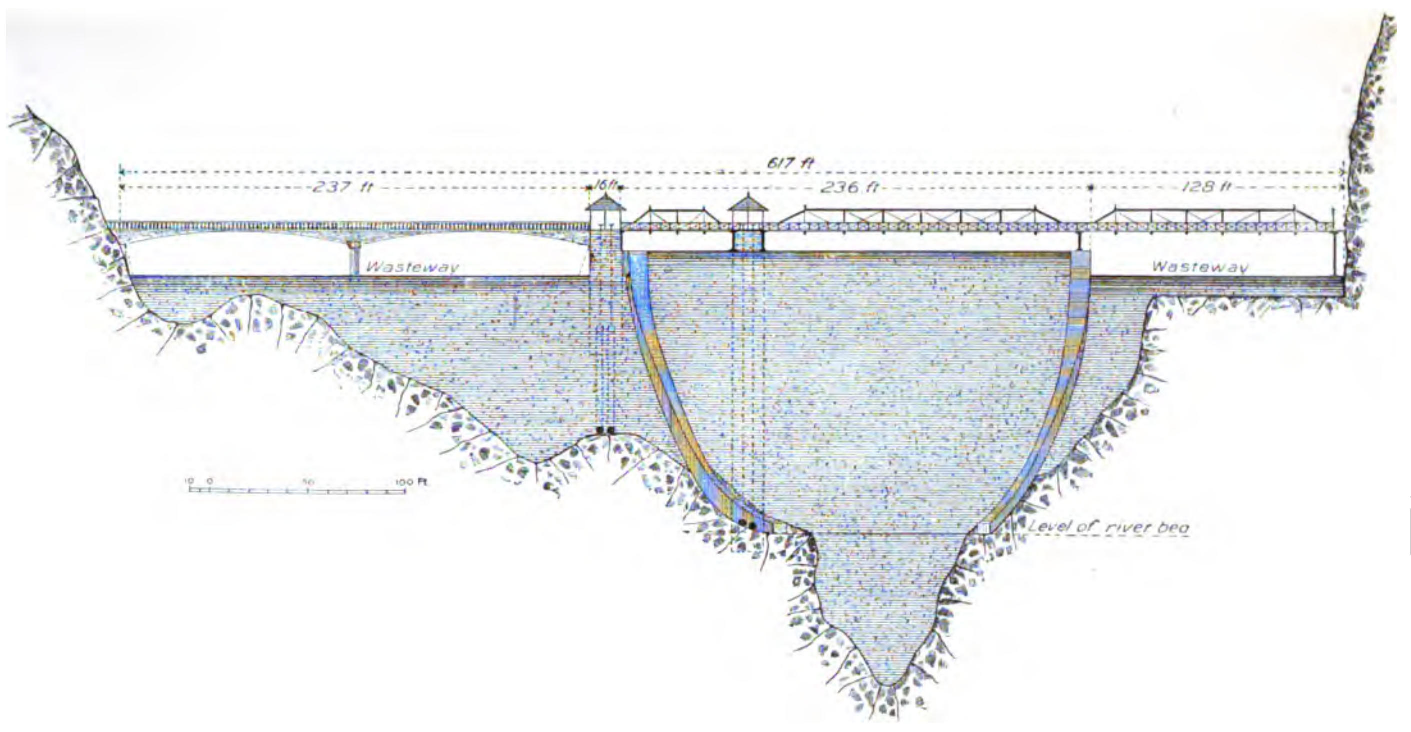
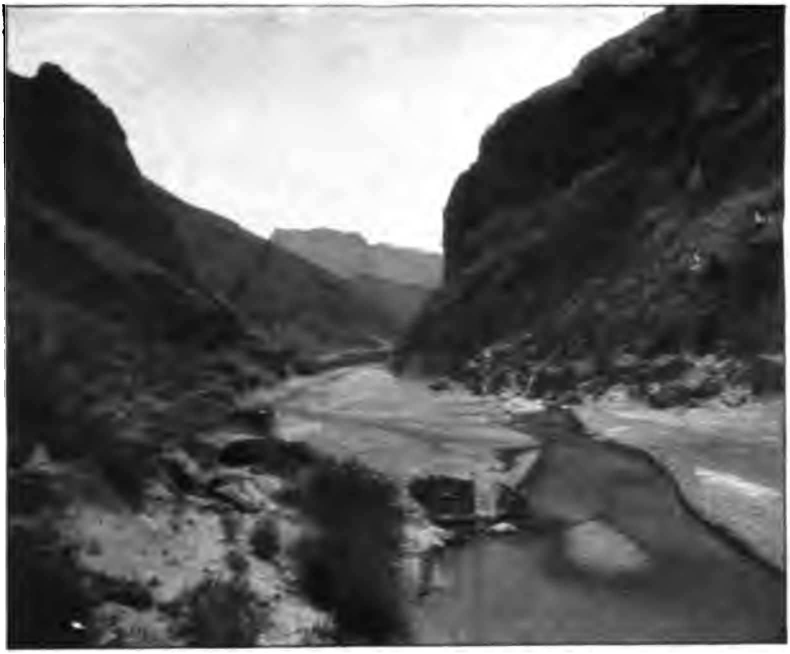


FIG. 10.—Maximum cross section of San Carlos dam.

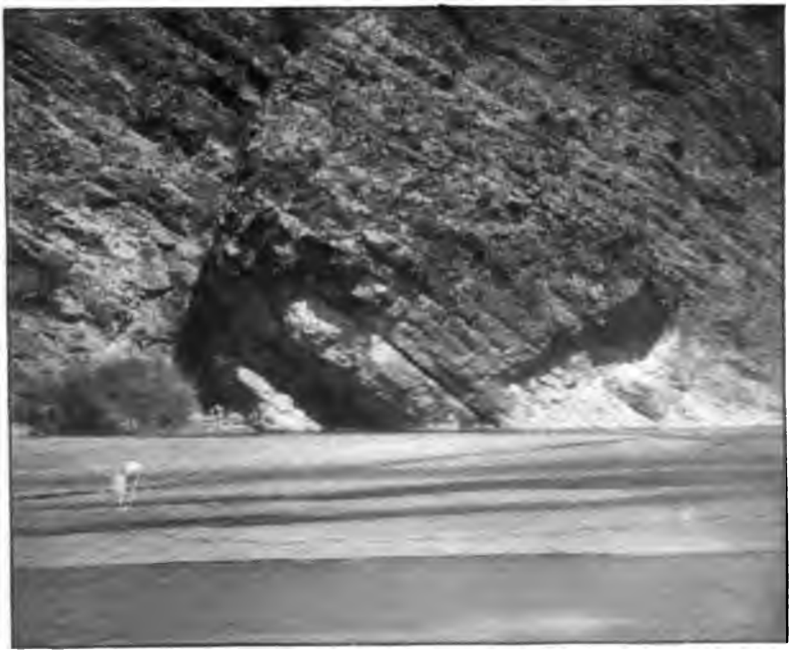
No one familiar with placer mining on a large scale will question the efficiency of the above methods for the cheap removal of large quantities of material when it is remembered that this material is usually loose and soft. Some of the silt will be deposited in the long stretch of canyon which is now kept clear by the great floods it is pro-



ELEVATIONS OF PROPOSED SAN CARLOS DAM AND WASTEWAY.



A. SAN CARLOS DAM SITE, LOOKING DOWNSTREAM.



B. LEFT ABUTMENT OF SAN CARLOS DAM SITE.

posed to store. Such of it as reaches the diversion canal can be disposed of by small settling basins provided with sluiceways, as is usual in all irrigated countries; or, if desired, can be carried upon the irrigated land, where it has considerable value as a fertilizer. In Europe silt-laden waters, by reason of their fertilizing value, command much higher prices than those that are clear. Observations of sediment at San Carlos have been taken for nearly a year and indicate an average annual inflow of about 8,000 acre-feet of solid matter. It is estimated that 20 per cent of this can be drawn off with irrigating water, leaving 6,000 acre-feet deposited in the reservoir. Experience in hydraulic mining indicates that by the proposed process it will cost about 1 cent per cubic yard, or $18 per acre-foot, to remove this, making an annual charge of $108,000, to be borne by the irrigated land, or less than two dollars per acre per annum.

COST OF THE PROJECT.

Plans and estimates of the cost of storing water at San Carlos were prepared by Mr. J. B. Lippincott and were examined by Mr. James D. Schuyler, his report being printed in Part IV of the Twenty-first Annual Report of the Geological Survey, pages 358–379. The maximum depth to bed rock assumed in preparing the plans is 78 feet. Before construction can be safely undertaken it will be necessary to continue the examination of the dam site and ascertain the exact depth and condition of the bed rock. The cost of a masonry dam, as estimated from the various data, has been placed at about $1,400,000. This should furnish water for the irrigation of at least 100,000 acres. It is considered feasible to raise the dam 70 feet higher than contemplated in the estimates, and in the working plans provisions for such

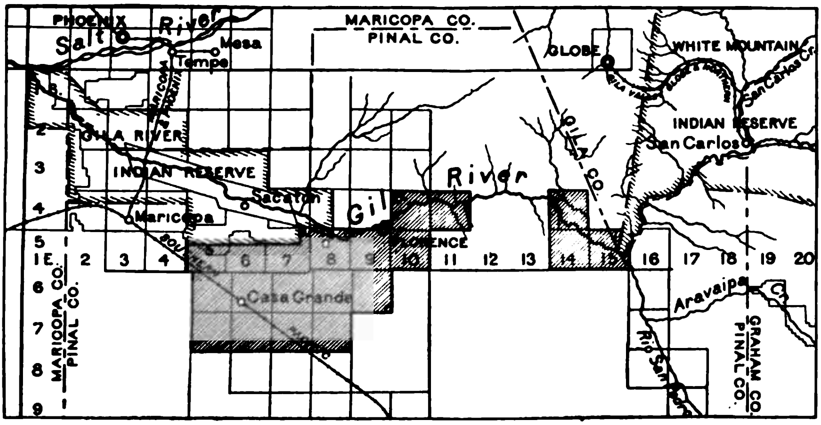


FIG. 11.—Map of lands temporarily withdrawn pending the survey of the San Carlos project.

an extension should be made in order to provide for additional storage if the lower part of the reservoir is filled with mud.

As a preliminary to further work, the lands which may be benefited by the construction of this dam have been withdrawn from entry. Some of the best land is now in private ownership, and for the ultimate working out of the project it will be necessary for the owners of these lands to make a proposition within the letter of the law which can be favorably considered from a financial standpoint.

Summarizing the general results, it may be said that the proposed San Carlos reservoir in southern Arizona, on Gila River, is to supply water for about 100,000 acres of arid lands in public or private ownership. The capacity of the reservoir is 240,000 acre-feet. The flood water stored will be turned back into the river and will flow through rocky canyons to the point of diversion, where a canal can be constructed, largely by Indians and white settlers, to take water to the reservation and to Government lands. The estimated cost of diversion works and canal is $160,000.

Estimated cost of San Carlos reservoir.

Masonry	$690,000
Excavation, pumping, etc	150,000
Outlet tunnel, towers, gates, etc	25,000
Removal of railway and agency	110,000
New irrigation system above reservoir	20,000
Miscellaneous items	45,000
Total cost of reservoir	1,040,000
Diversion works and canal	160,000
	1,200,000
Engineering and contingencies (15 per cent)	180,000
	1,380,000

The results of this work will be a supply of water for the future needs of a large tract of land now arid or only partly tilled.

VERDE RIVER PROJECT.[a]

Verde River is a tributary of Salt River, entering it from the north about 30 miles above Phœnix, Ariz. It furnishes a little less than one-half the water supply of the canals of the Salt River Valley. The area drained at the mouth of the river is 6,000 square miles. In order to consider plans for the increase of the water supply of this valley surveys of a reservoir site known to exist there were inaugurated in 1901 under Mr. Arthur P. Davis.

The locality known as the McDowell dam site is about 2 miles above the mouth of the river. The depth and character of the bed rock were determined by means of boring machines and diamond drills. The dam

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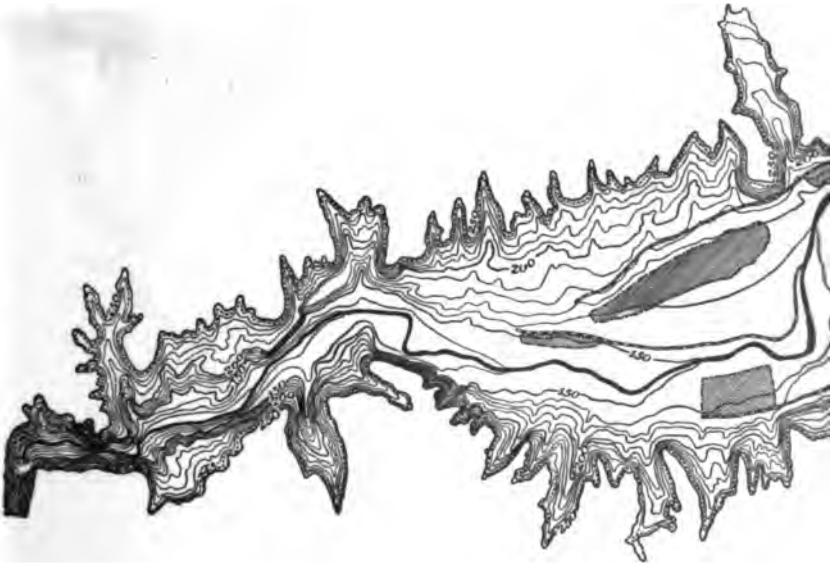
[a] From report by Arthur P. Davis.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150
150

site was mapped on a scale of 100 feet to 1 inch and with 5-foot contours, and the reservoir site was mapped on a scale of 1,000 feet to 1 inch and with 10-foot contours. The field work was largely executed by Mr. E. G. Hamilton and Mr. C. R. Olberg, under the general direction of Mr. F. P. Trott, water commissioner of Salt River, who had also made certain preliminary surveys of the site.

The flow of Verde River at Mount McDowell was directly observed by the Hudson Reservoir Company from February 4, 1895, to July 31, 1896, and by the Geological Survey from April 20, 1897, to November 30, 1899, and during 1901. The remainder of the record from August, 1888, to January 1, 1902, is computed by taking a proportional part of the discharge of Salt River at Arizona dam, below the mouth of Verde River, as measured by the various canal companies. The annual discharges, so far as completely known, are as follows:

Annual discharge of Verde River.

Year.	Discharge.	Remarks.
	Acre-feet.	
1888......	[a]261,735	Proportional discharge of Salt River at Arizona dam.
1889......	742,028	Do.
1890......	1,186,843	Do.
1891......	1,371,760	Do.
1892......	[b]129,861	Do.
1893......	568,000	Do.
1894......	188,427	Do.
1895......	762,564	Eighteenth Annual Report, Part IV, p. 297.
1896......	293,629	Do.
1897......	513,705	Nineteenth Annual Report, Part IV, p. 423.
1898......	226,153	Twentieth Annual Report, Part IV, p. 407.
1899......	217,914	Twenty-first Annual Report, Part IV, p. 387.
1900......	116,679	Data from F. P. Trott.
1901......	301,915	Observations of U. S. Geological Survey.

[a] Partial record, August to December, inclusive.

[b] February to June, inclusive, approximate—filled in from minimum discharge recorded—i. e., same months for 1900.

The greatest flood that has occurred in the Salt River Valley since its settlement was in February, 1891, and is described in the Twelfth Annual Report.[a] The maximum discharge was computed at 300,000 second-feet, contributed from both Verde and Salt rivers.

The drainage area above the McDowell site is less than one-half the area from which the flow above given was drawn, but with due consideration for providing sufficient spillway capacity for 200,000 second-feet, or two-thirds of the 1891 flow, which figure has been assumed as the maximum flow of the Verde. The discharge of the spillway is computed from the formula: $Q=3.5lh^{\frac{3}{2}}$. At the McDowell site it is found that a spillway 900 feet long and 15 feet from the top of the dam would discharge safely the maximum flow. The following table shows the capacity of the reservoir site for every 10-foot contour, zero elevation being at the lowest point of the foundation of the proposed dam:

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[a] Twelfth Ann. Rept. U. S. Geol. Survey, Part II, Irrigation, p. 31.

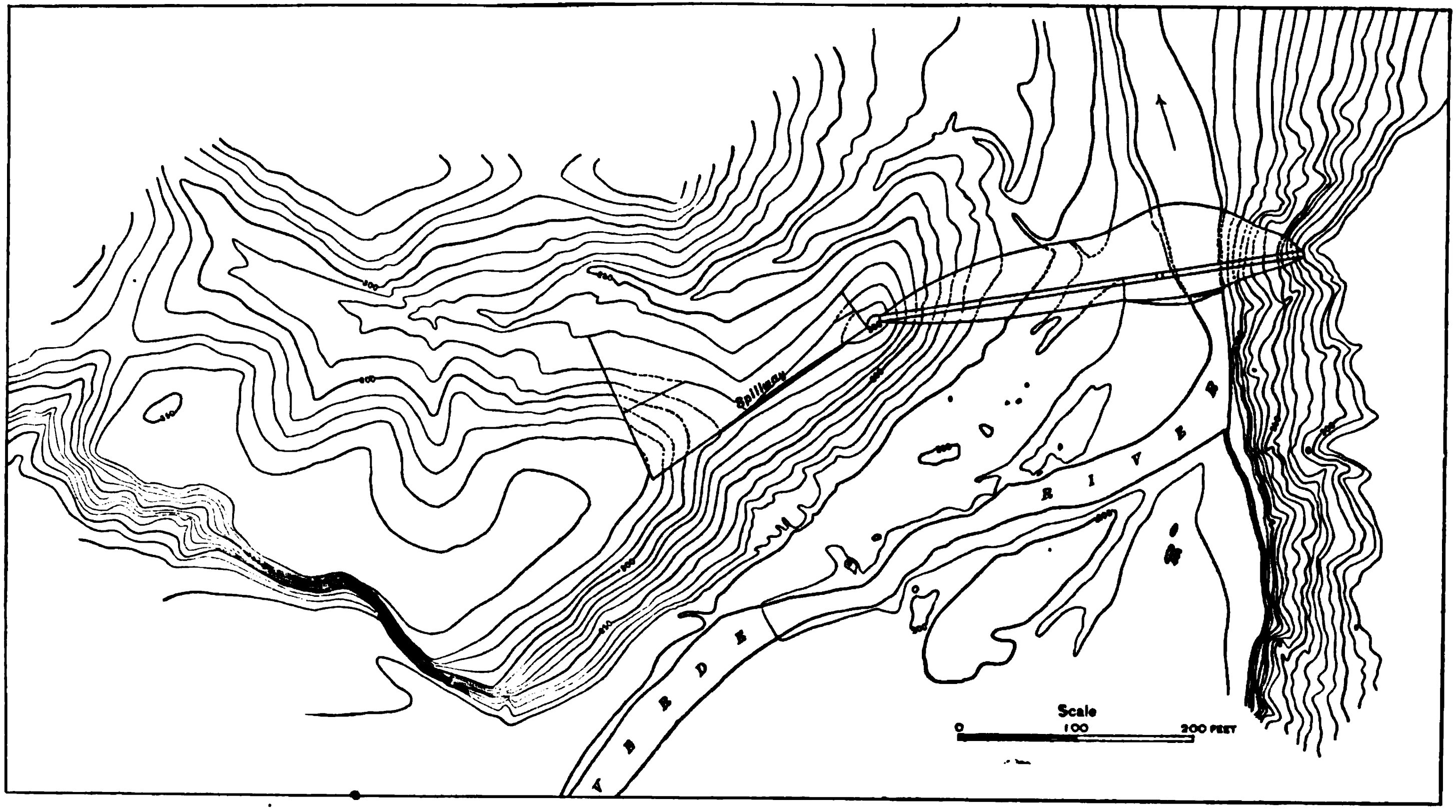
Capacity of McDowell reservoir on Verde River.

Elevation above lowest foundation.	Area.	Capacity of section.	Total capacity.
	Acres.	*Acre-feet.*	*Acre-feet.*
100	14	70	70
110	91	525	595
120	331	2,110	2,705
130	717	5,240	7,945
140	1,073	8,950	16,895
150	1,661	13,670	30,565
160	2,292	19,765	50,330
170	3,134	27,130	77,460
180	4,034	35,840	113,300
190	4,990	45,120	158,420
200	6,020	55,050	213,470
210	7,213	66,165	279,635

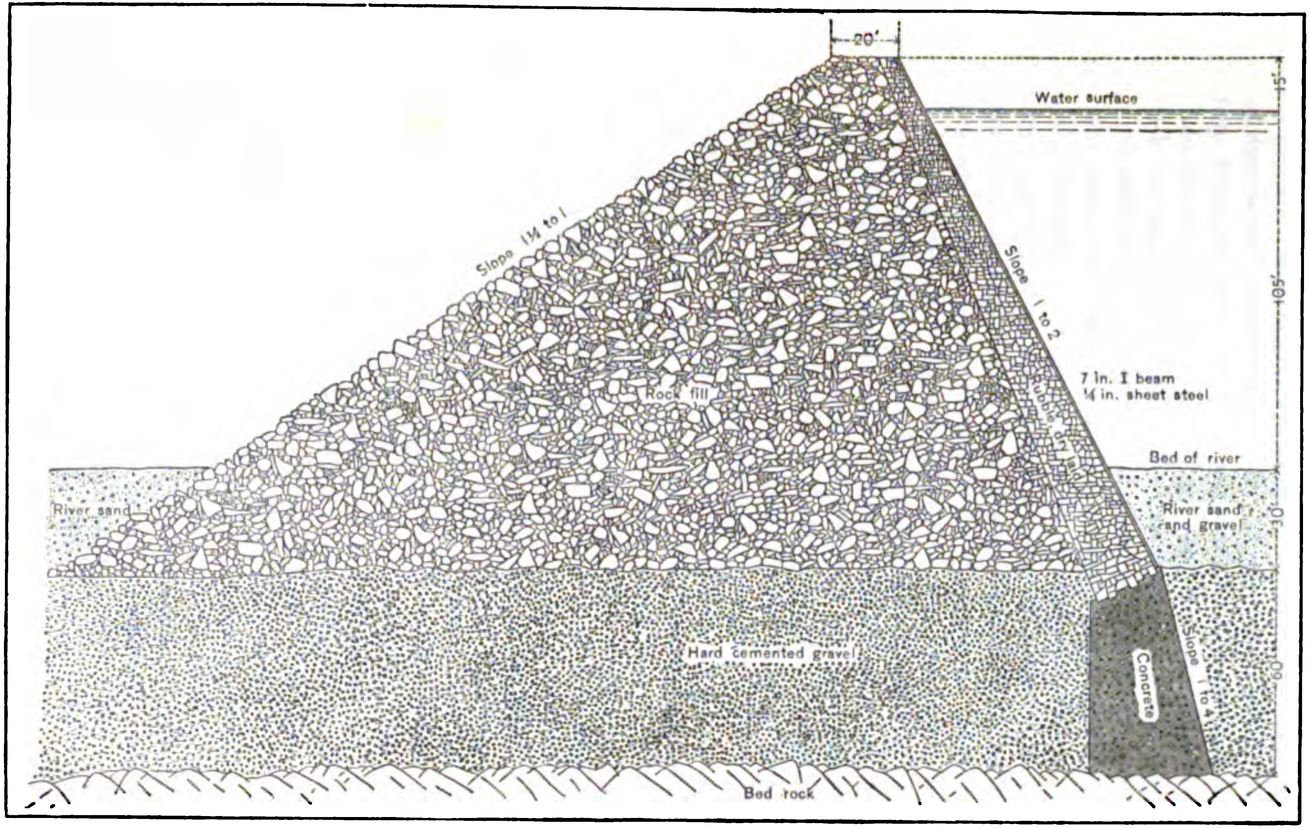
The borings at the dam site show 30 feet more or less of river gravels. Under this occurs a hard cemented mixture of sand and gravel extending to bed rock, which was found at the maximum depth of 90 feet. The depths of the borings are shown in the following table:

Depth to bed rock at McDowell dam site on Verde River.

Hole No.	Distance from B. M.	Depth to bed rock.	Total depth of hole.	Remarks.
	Feet.	*Feet.*	*Feet.*	
1	20	22	22	Granite.
2	40	35	38	Rotten granite.
4	80	90	99	Broken granite.
6	120	80	92	Do.
8	160	49	59	Granite.
10	200	40	46	Hard gray granite.
12	240	52	65	Broken granite.
21	....	22	26	Granite.
25	....	....	90	No bed rock reached.
28	....	....	50	Do.



CONTOUR MAP OF McDOWELL DAM SITE.



SECTION OF PROPOSED McDOWELL DAM.

In the construction of a masonry dam it would be necessary to excavate through this cemented gravel to reach bed rock. The cost of such excavation and construction would be prohibitive, and therefore this type of dam is not considered feasible. A plan of a rock-fill dam has therefore been adopted, and it is without doubt more suitable. The west abutment is a mountain of granite from which will be obtained rock for use in the dam. The east abutment is less favorable. The granite bed rock appears on the surface on the east side of the river, but seems to enter the hill on a nearly horizontal grade. The hill above the granite, which constitutes the upper 90 feet of the abutment, is composed of an indurated mixture of coarse sand and gravel of the same character as the foundation described above, too hard to excavate with a pick, but not to be classified as rock, and inclined to disintegrate upon exposure to air. It is probable that, under high head, water might percolate through this material to some extent, at least where the abutment is thinnest, and to insure against this a concrete core is to be carried into the hill a distance of about 300 yards, where the hill becomes over 1,000 feet thick. Supposing this core to be 6 feet in thickness, the excavation and masonry would cost about $600 per running yard, and hence would add $180,000 to the cost of the construction. It should be the attempt to make as thorough a bond as possible between the concrete core and the adjacent natural deposit, by filling the joint with Portland cement concrete well rammed in place, so that there can be no creeping of water along the wall. With proper precautions it is believed that a dam of the proposed height, 120 feet, could be safely built and maintained at this point.

At the site of the dam the river bed is composed of ordinary sand and gravel to a depth of about 30 feet, when the compact cemented gravel is encountered. The depth to bed rock is about 90 feet at the deepest point. It is proposed to carry a concrete wall down to bed rock across the canyon at the upstream toe of the dam. This wall will be 35 feet thick at the base on bed rock and diminish to 15 feet at the top. Downstream from this wall the river sand and gravel will be excavated to the cemented material above mentioned, and upon this will be founded the main dam, which is to be of the rock-fill type, the upstream face to be on a slope of 1 in 2 and the downstream slope 3 in 2, with a top width of 20 feet. The rock will be obtained from the mountain of granite that rises abruptly from the west abutment. The rock can be transported down grade on a cableway and dropped on the dam in large blocks from a considerable height, which will serve to ram it solidly in place, and it is believed very little settlement will occur. On the upstream face is to be a wall of dry rubble resting on the concrete wall that goes down to bed rock. The rubble will have a thickness of 20 feet at the bottom, diminishing to 5 feet at the top. Against its downstream side will be built the mass of dry rock-fill. On the water face, which will have a slope of 1 in 2, will be placed, at intervals of 20 feet, a series of 7-inch **I**-beams, each extending from the bottom to the top of the dam. To these beams will be fastened a floor of one-fourth-inch steel plates dipped in asphalt and riveted together to form a water-tight skin over the entire water slope of the dam. The space between the steel plates and the rubble will be filled with concrete tightly rammed. The concrete and rubble walls will unite at the ends with the concrete core, which is to be carried into the east abutment, as above described.

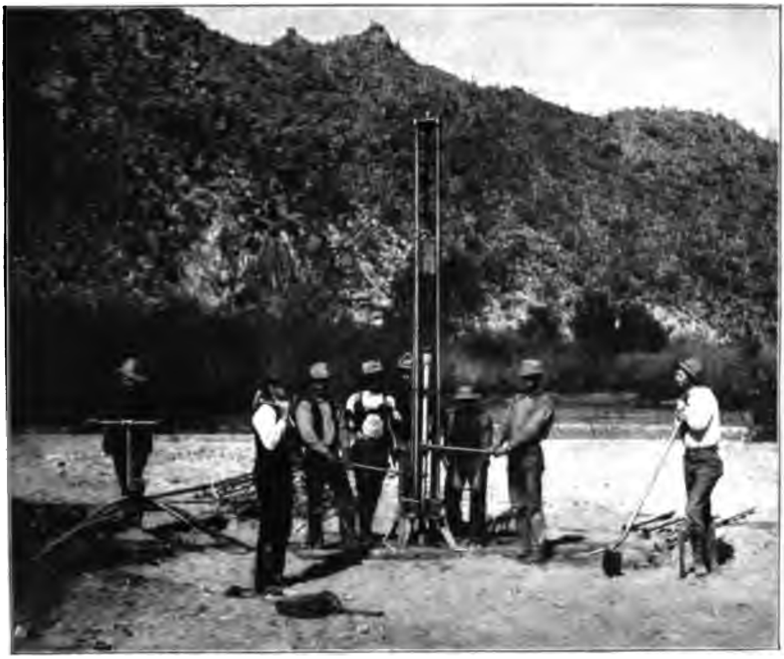
The outlet would be through a tunnel of concrete built through the dam along the bed of the river, provided with Stoney gates, similar in construction and mechanism to those for the Salt River reservoir. All water will be drawn from the bottom of the reservoir, and whenever the spillway begins to discharge the gates will be opened to full capacity for the purpose of discharging the maximum quantity of silt and of reenforcing the spillway.

For diverting the river during construction a temporary diversion dam could be placed across the river about 4,000 feet above the dam site, and the water diverted into a large flume and carried along the east side of the river over the portion of the foundation where granite bed rock appears on the surface. The underflow can probably be sufficiently checked by driving sheet piling down to the bed of indurated gravel by which the valley is underlain at a depth of about 30 feet. After the dam becomes too high to use the flume the discharge will be through the outlet tunnel. The flume should be removed early in the spring, at the beginning of the low-water season, and construction pushed rapidly, so as to have a large storage and discharge capacity ready for the first flood.

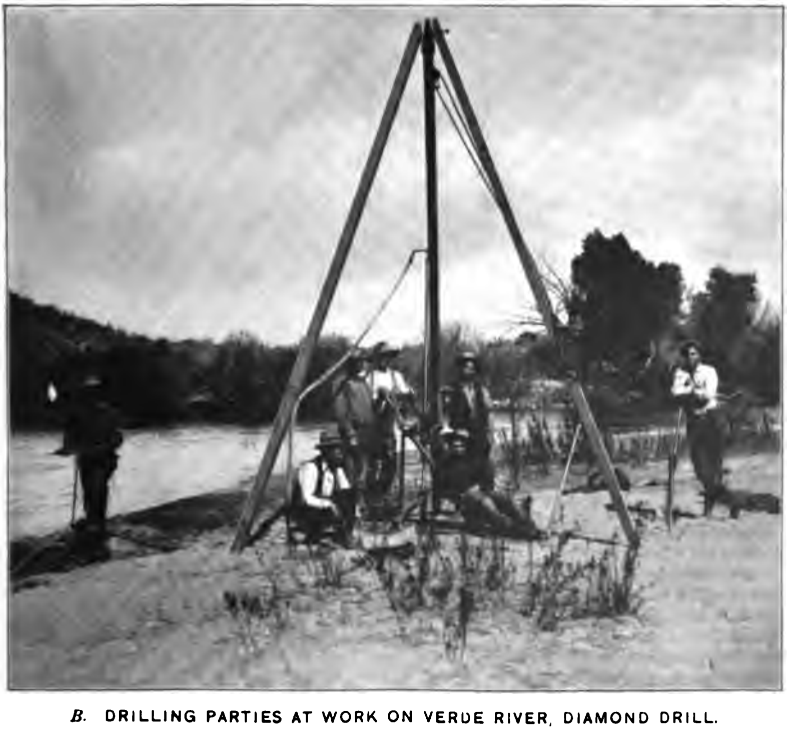
Estimate of the cost of the McDowell dam on Verde River.

745,875 cubic yards rock fill, at 80 cents	$596, 700
78,155 cubic yards dry-laid rubble, at $2	156, 310
7,865 feet, or 117,975 pounds, **I**-beam, at 7 cents	8, 258
140,680 square feet ¼-inch plates, or 1,434,936 pounds, at 7 cents	100, 585
Excavating 58,667 cubic yards cemented gravel, at $1	58, 667
Excavating 125,000 cubic yards sand, at 20 cents	25, 000
5,210 cubic yards concrete, under steel apron, at $10	52, 100
18,792 cubic yards concrete in toe wall, at $10	187, 920
Diversion of river	10, 000
Outlet gates, tower, etc	20, 000
Concrete core wall to be carried into east abutment	180, 000
Engineering and contingencies, 15 per cent	209, 331
Right of way	20, 000
	1, 624, 871

Capacity of reservoir, 186,000 acre-feet.
Cost per acre-foot capacity, $8.74.

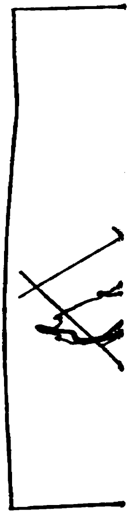


A. DRILLING PARTIES AT WORK ON VERDE RIVER, PIERCE RIG.



B. DRILLING PARTIES AT WORK ON VERDE RIVER, DIAMOND DRILL.

U. S. GE
DAM SITE



SALT RIVER PROJECT.[a]

The main project for the increase of the water supply of Salt River Valley contemplates the storage of water on Salt River in its canyon about 45 miles above the mouth of Verde River, and a short distance below Tonto Creek. The investigation of this locality was begun at the request of the Maricopa County Water Storage Commission, and was carried on in cooperation with this organization.

The reservoir site was mapped on a scale of 1,000 feet to 1 inch and with 5-foot contours. Borings were also made at the dam site to determine the depth and character of the bed rock. The dam site is located a short distance below the mouth of Tonto Creek, so that if water is stored here it will be backed up this creek as well as Salt River, and form a reservoir of enormous proportions, as shown in the following table (p. 92), which gives the capacity of the reservoir site for every 10 feet in elevation above the river up to 200 feet.

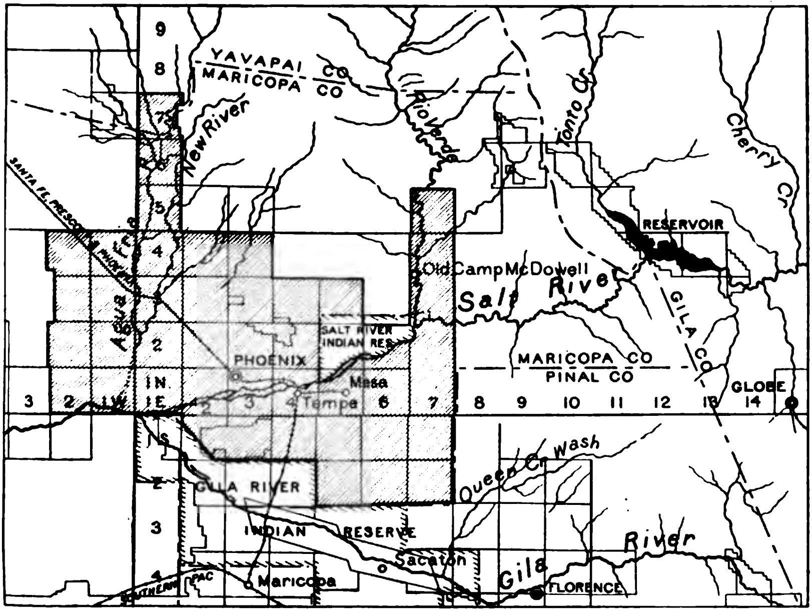


FIG. 12.—Map of lands temporarily withdrawn on Salt River, Arizona. (Additional land has been reserved since this map was drawn.)

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[a] From report by Arthur P. Davis.

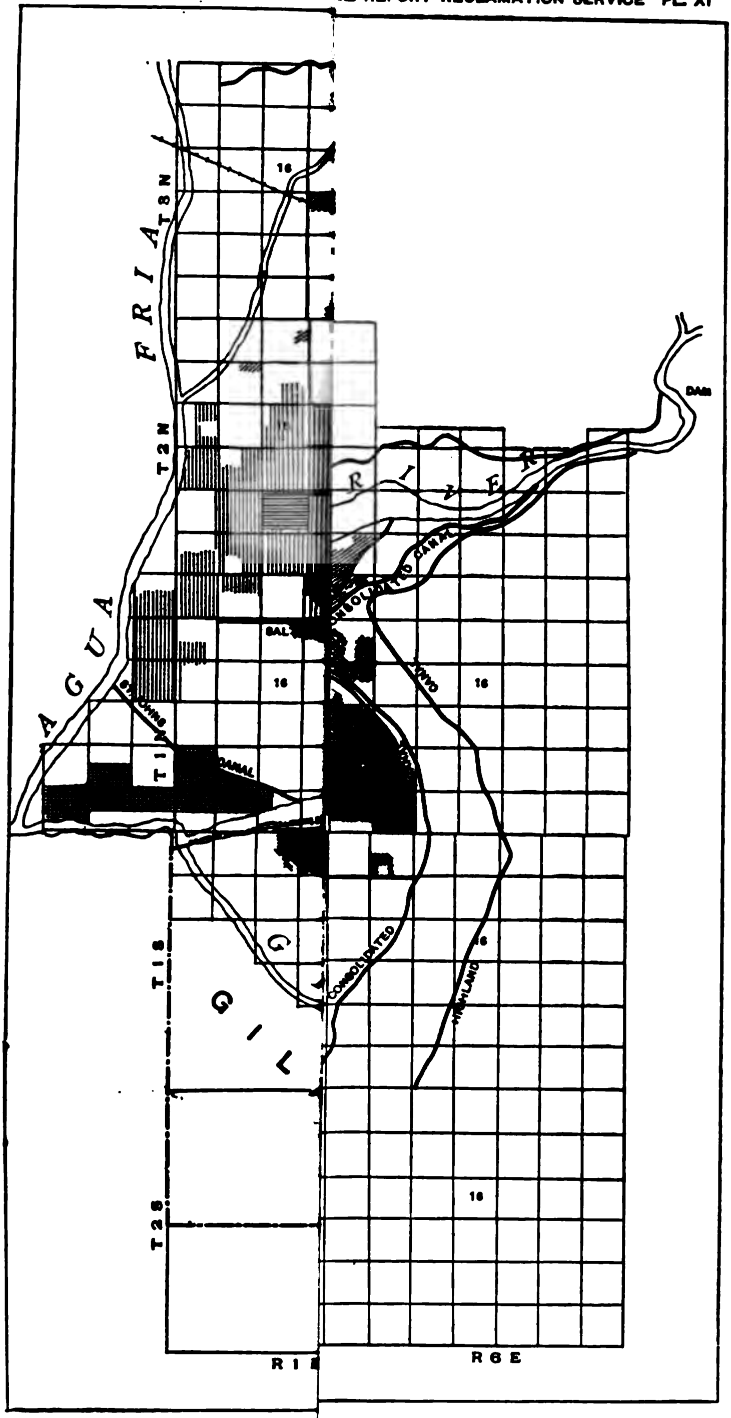
Capacity of Salt River reservoir.

Height above low water.	Area.	Capacity of section.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
10	24	120	120
20	128	760	880
30	224	1,760	2,640
40	401	3,125	5,765
50	694	5,475	11,240
60	1,085	8,895	20,135
70	1,458	12,715	32,850
80	2,103	17,805	50,655
90	2,930	25,165	75,820
100	3,682	33,060	108,880
110	4,391	40,365	149,245
120	5,536	49,635	198,880
130	6,394	59,650	258,530
140	7,293	68,435	326,965
150	8,411	78,520	405,485
160	9,664	90,375	495,860
170	10,769	102,165	598,025
180	12,158	114,635	712,660
190	13,459	128,085	840,745
200	14,617	140,380	981,125

The water supply is computed from several sources. The data for 1901 are from measurements made at the dam site; those from April, 1897, to November 30, 1899, are computed from measurements made on Salt River above the mouth of the Verde by the Hudson Reservoir Company. For several years previous and for 1900 computations are from the records of the canal companies of the Salt River Valley.

If the water of this stream is stored and the reservoir is operated in connection with the natural flow of Verde River, an annual consumption of 660,000 acre-feet can be allowed. Verde River, so used, would supply the necessary water for the irrigated lands for the four months from December to March, inclusive, while its flow for the remainder of the year could be supplemented from the Salt River reservoir.

U. S. GEOLOGICAL SURVEY AL REPORT RECLAMATION SERVICE PL. XI



The annual discharge of Salt River at the reservoir site from 1888 to 1901 is given in Water-Supply Paper No. 73, pp. 26–29. The discharge for 1902 is given in the following table:

Estimated monthly discharge of Salt River at Reservoir site below Tonto Creek in 1902.

[Drainage area, 5,756 square miles.]

Month.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
January	236	176	189	11,621	0.033	0.038
February	236	204	207	11,496	.035	.037
March	236	97	201	12,359	.035	.040
April	350	163	268	15,947	.046	.051
May	272	72	167	10,268	.027	.031
June	204	65	106	6,307	.018	.020
July	163	45	78	4,796	.013	.015
August	4,675	52	478	29,391	.083	.096
September	4,425	138	1,057	62,896	.183	.204
October	190	126	131	8,055	.022	.025
November	431	126	189	11,246	.032	.036
December	2,700	150	438	26,931	.076	.088
The year	4,675	45	292	211,313	.050	.681

PLANS FOR THE DAM.

Explorations for bed rock were first undertaken at a narrow point in the canyon. Six holes were sunk in this line, which was known as "Line A." The maximum depth reached was about 65 feet.

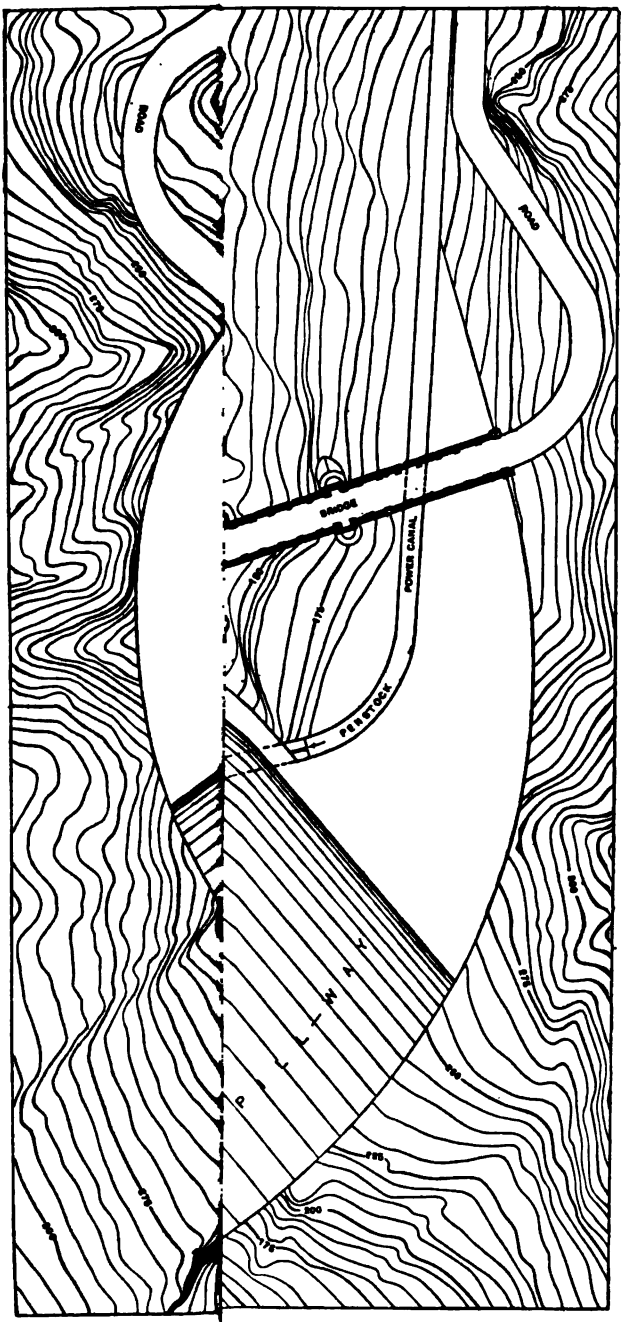
It was found by surface indications that bed rock was nearer the surface at a point about 1,000 feet lower down the canyon, and the boring machinery was therefore moved down to this location, which was the one finally adopted for the dam site, although the canyon here is somewhat wider than the one above. The maximum depth found was about 31 feet. Three lines of holes were sunk, known as B, C, and D, with 100 feet between the lines.

The various depths of the four lines are shown in the following table:

Depth to bed rock at Salt River dam site.

No.	Bed rock.	Total depth.	Character of rock.
LINE A, HUDSON RESERVOIR COMPANY SITE.	*Feet.*	*Feet.*	
1	24.0	39.5	Red sandstone.
2	28.0	35.3	Sandstone.
3	64.5	74.0	Coarse, soft white sandstone.
4	44.0	49.8	Broken quartzite.
5	23.0	25.3	Do.
6	24.0	30.0	Do.
LINE B, 1,600 FEET BELOW LINE A.			
1	22.5	22.5	Red sandstone.
2	26.7	31.7	Do.
3	25.5	25.5	Do.
4	25.8	31.3	Do.
5	28.0	28.0	Do.
6	25.0	31.3	Do.
7	24.7	24.7	Do.
8	22.2	26.7	Do.
9	20.0	20.0	Do.
LINE C, 100 FEET BELOW LINE B.			
1	22.0	22.0	Red sandstone.
2	21.0	25.9	Do.
3	22.5	27.0	Do.
4	22.0	22.0	Do.
5	23.0	33.4	Do.
6	24.0	24.0	Do.
7	23.8	39.0	Do.
8	22.0	22.8	Do.
9	24.6	27.0	Do.
LINE D, 100 FEET BELOW LINE C.			
1	....	....	
2	23.5	28.0	Black slate.
3	....	....	
4	23.5	26.4	Do.
5	25.0	....	Do.
6	31.0	34.5	Do.
7	30.3	30.7	Do.
8	21.5	24.2	Do.
9	....	....	Do.
10	21.5	23.0	Do.

U. S. GEOLOGICAL S REPORT RECLAMATION SERVICE PL. XII



The gorge on Salt River offers an especially favorable site for a masonry dam, the most permanent, conservative, and secure form of construction for a high dam that is known to engineering science. The formation is sedimentary, with the strata inclined at an angle of about 30° to the horizontal, dipping toward the reservoir, a most favorable condition for retaining stored waters and for the stability of the dam. The foundation and abutment of hard, tough, fine-grained sandstone are all that could be desired. Building stone of the same material is at hand and above the site. As elsewhere set forth, good Portland cement can be made near the site. Sand for mortar can be obtained from the river bed, but will have to be washed and screened, and it is thought that the best plan will be to manufacture sand by crushing quartzite, which occurs in abundance near the site. This will provide an ideal sand, and as power is abundant, its cost will not be great.

The proposed dam is designed to be 217 feet above datum, which is low water in the river at the dam site, and to store water at a maximum depth of 190 feet, the total height of dam above lowest foundation being about 245 feet. Spillways 20 feet deep will be excavated in the solid rock sides of the canyon, and the rock used in the construction of the dam. The location lends itself admirably to a curved form of dam, this form containing but little more material than a straight one of the same section. The proposed structure is to be built on a circular curve, convex upstream, the back having a radius of 400 feet, and the face a shorter radius from the same center. The dam is to be of uncoursed rubble masonry, and to have a section on modern conservative ideas as a simple gravity structure, and the added stability due to its curved form will greatly increase its factor of safety. The rock of which the dam will be constructed will be excavated from the spillways, and is a tough, close-grained sandstone. A sample was taken from each side of the canyon and tested for specific gravity in the laboratory of the United States Geological Survey. The following are the results of this test:

Specific gravities of two specimens of sandstone.

I. Determined on lumps:
    A. In ordinary distilled water as quickly as possible.
        No. 1.—Specific gravity, 2.42 at room temperature.
        No. 2.—Specific gravity, 2.47 at room temperature.
    B. After soaking in distilled water twenty-four hours.
        No. 1.—Specific gravity, 2.44 at room temperature.
        No. 2.—Specific gravity, 2.49 at room temperature.
    C. After standing in distilled water under the air pump for twenty-four hours.
        No. 1.—Specific gravity, 2.50 at room temperature.
        No. 2.—Specific gravity, 2.52 at room temperature.
II. Determined on the powdered samples:
        No. 1.—Specific gravity, 2.583 at 21.5° C., compared with water of same temperature.
        No. 2.—Specific gravity, 2.611 at 17.5° C., compared with water of the same temperature.

Tests for crushing were also made and are given below.

Two cubes with edges of 2 inches were cut from samples of the rock and crushed in the testing machine at the United States navy-yard in Washington.

Sample No. 1 crushed at 59,650 pounds, being 14,912 pounds per square inch, or 1,074 tons per square foot.

Sample No. 2 crushed at 100,000 pounds, being 1,800 tons per square foot. These results are so high that the strength of the rock is entirely eliminated from the discussion.

It is proposed, as described later, to manufacture on the ground the cement to be used in the dam, as the requisite ingredients have been found near by. Two cubes of 1 cubic inch each were cut from briquettes of neat cement, manufactured from material obtained near the site, and were also tested at the United States navy-yard.

Sample No. 1 crushed at 6,690 pounds, or 482 tons per square foot.

Sample No. 2 crushed at 8,840 pounds, or 636 tons per square foot.

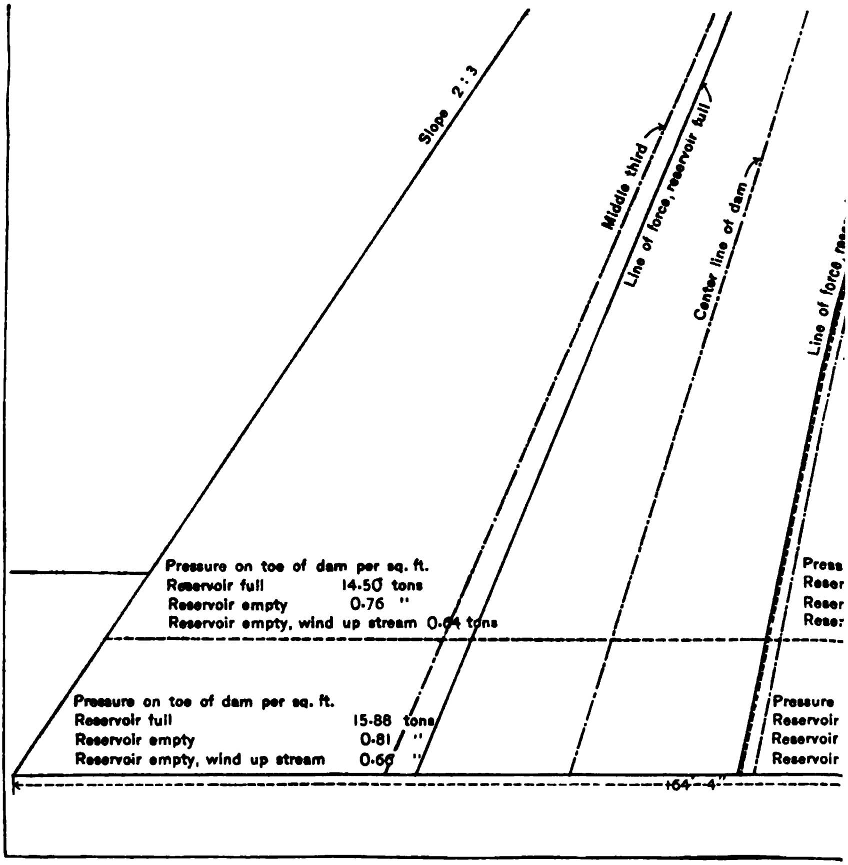
The dam is so designed that the line of pressure will always fall within the middle third. The pressure in the toe, with full reservoir, will be 15.9 tons per square foot. The maximum possible pressure, 16.64 tons, occurs at the heel when the reservoir is empty and a strong wind is blowing upstream.

OUTLET WORKS.

For the purpose of facilitating the discharge of sediment from the reservoir, and also to furnish the maximum reenforcement to the spillways, it has been decided to draw all water from the reservoir through large openings directly on the bottom. Accordingly, the plan adopted is to have two tunnels dug through the solid rock, one on each side of the canyon. Each tunnel will be provided with two gates, each 6 feet by 10 feet 3½ inches, with a clear opening of 5 feet 4½ inches by 10 feet, making a total area of 215 square feet clear opening. This would have a discharge capacity of about 1,500 cubic feet per second with water standing in the reservoir on a level with the top of the tunnel. The tunnel capacity will be 12,000 square feet with water at height of spillway, and 14,000 square feet with spillway running full. In the latter case the maximum head on the gates would be 190 feet, producing a mean pressure of 11,600 pounds per square foot. The gates, to withstand this great pressure, will be built of I beams, channel irons, and steel plates, and will bear on solid steel rollers placed to eliminate friction. Each gate will be worked by two hollow rods and screws operated by electric motors.

POWER PLANT.

In the construction of a great dam one of the most important elements is power. It is necessary on a large scale for drilling purposes, for handling rock, for mixing and handling mortar, and for crushing the rock used in concrete.


Slope 2 : 3
Middle third
Line of force, reservoir full
Center line of dam
Line of force, res
Pressure on toe of dam per sq. ft.
Reservoir full 14.50 tons
Reservoir empty 0.76 "
Reservoir empty, wind up stream 0.64 tons
Pressure on toe of dam per sq. ft.
Reservoir full 15.88 tons
Reservoir empty 0.81 "
Reservoir empty, wind up stream 0.66 "
Press
Reser
Reser
Rese
Pressure
Reservoir
Reservoir
Reservoir
64' 4"

MAXIMUM CROSS SECTION OF PROPOSE

It is planned to develop a hydraulic power for the Salt River dam. The proposed canal for this plant would head some distance above the reservoir, following above its water line, and finally discharging just below the dam with an available head of about 180 feet. It is designed to deliver 100 second-feet and develop a net energy of 1,200 horsepower, 300 to be used at the cement mill and 900 at the dam.

The following is the estimated cost of the power installation:

Estimated cost of power plant at Salt River dam site.

Diversion works:		
Dam	$10,000	
1,000 feet of flume	3,200	
75,200 feet of canal	85,000	
3,300 feet of tunnel, at $6	19,800	
		$118,000
Water wheels, etc.:		
9 wheels, shafts, nozzles, housings, etc	7,350	
3 pairs couplings for attaching dynamos	555	
270 feet 22-inch pipe for penstock	1,600	
Receiver and nine branches	1,555	
Freight on 140,000 pounds, at 3 cents	4,200	
Power house	10,000	
		25,260
Electric plant:		
Three 300-kilowatt dynamos and exciters	24,000	
Transformers and motors	35,000	
Transmission lines	1,000	
Freight and installation	12,000	
		72,000
Total cost of power plant		215,260

SPILLWAY PROVISION.

The maximum flow of Salt River has been computed from the great flood of February, 1891, described under "Verde River improvement." This discharge for Salt River has been placed at 220,000 second-feet. It is assumed that the reservoir is full up to the bottom of the spillway, and that a great flood occurs, with a mean discharge for the first hour of 120,000 second-feet, and increases its discharge 10,000 second-feet during each succeeding hour for eleven hours, at the end of which time it has reached its maximum wave of 220,000 second-feet. The discharge then diminishes in arithmetical progression for twenty hours at the rate of 5,000 second-feet per hour, reaching the discharge of 120,000 second-feet as a mean for the thirty-first hour. The spillway, as planned, has a length of 350 feet, and its bottom is 27 feet below the top of the dam. At the end of the thirty-first hour the surface of the water has reached an elevation of 209.6 feet, or 7.4 feet below the top of the dam. The spillway has, at this elevation, a discharge of 119,760 second-feet. From this point the flood begins to decline. The above assumed flood wave might, therefore, be considerably exceeded without flowing over the dam. Hence the spillway provisions, as planned, are considered ample for all possible requirements. It should be noted, however, that the dam would not be injured or endangered by a very considerable flood over the top.

SEDIMENT.

Most of the streams of the Southwest carry a considerable amount of sediment, which will tend to fill a reservoir if provisions are not made for its disposal. It has been found that Salt River will give less trouble in this connection than the majority of the other streams of the section, owing to its basin lying in large part in a timbered, mountainous country. Observations made at the dam site, of the amount of sediment carried, are as follows:

Computations based on sediment observations of Salt River, below Tonto Creek, Livingstone, Ariz.

[Drainage area, 5,756 square miles.]

Month.	c. c. of water tested during the month.	Sediment.		Percentage of dry material to total amount of water tested.	Run-off in acre-feet for the month.	Total volume of dry material in acre-feet for the month.
		c. c. of wet material.	Grams of dry material.			
1901.						
January	3,100	....	.8065	.00026	27,945	7.27
February 1 to 15	1,500	48 (?)	.796	.00053	65,020	34.46
February 16 to 28	1,300		.1561	.00012	69,025	8.28
March	3,100	12	.307	.000099	87,472	8.66
April 1 to 18	1,800	....	.004	.0000021	30,290	.06
May 27 to 31	500 (?)	....	2.9475	.005895	4,877	28.75
July [a]	3,100	46	12.1644	.003924	21,296	83.57
August	3,100	51	12.7963	.004128	32,504	134.18
September	3,000	14.5	3.9969	.0013323	17,910	23.86
October	3,100	....	.1685	.000054	9,334	5.04
November	3,000	2	.1804	.000058	11,603	.67
The year	....	....	....	....	....	334.80
1902.						
January [b]	3,100	1	.0575	.0000185	11,621	.21
April [c]	3,000	....	.09	.00003	15,947	.48
May	3,100	2	.5	.0001613	10,268	1.66
July [d]	3,100	25	7.232	.0023225	4,796	11.14
August	3,100	112	29.15	.009387	29,391	275.89
September	3,000	57	19.57	.006523	62,896	410.27
November [e]	3,000	11	.92	.0003067	11,246	3.45
December	3,100	10	1.465	.0004403	26,931	1.86
The year	....	....	....	....	....	704.96

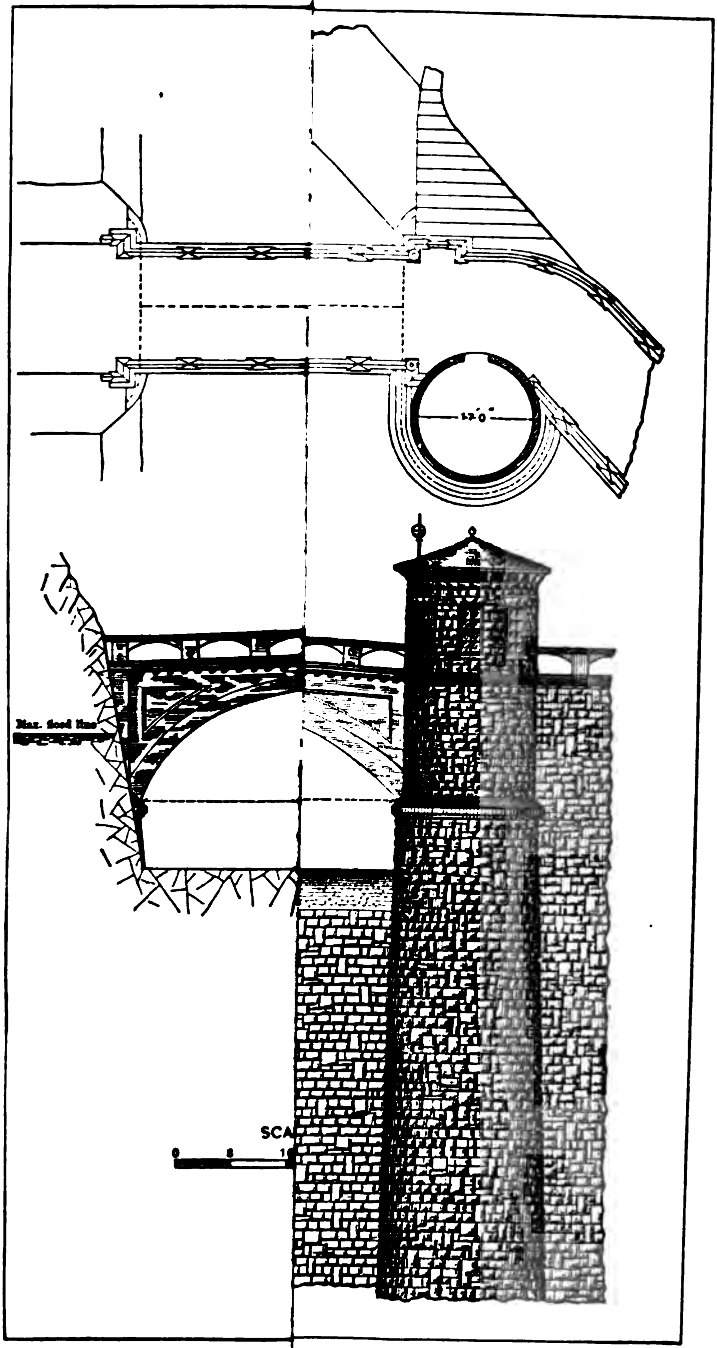
[a] Water clear in June.

[b] Water clear in December.

[c] Water clear in February; only trace of sediment in March.

[d] Water clear in June.

[e] Water clear in October.


12'0"
Max. flood line
SCA
0
8
1

The above table shows that during the period covered by the observations the sediment carried was very small in amount, almost negligible; but the discharge during the year was far below the normal, and it is believed that the portion of sediment shown by the observations is also below the normal. If we take 1,000 acre-feet as the average inflow of sediment, this will be nearly three times that observed during 1901, and yet it would require eight hundred and forty years to fill the reservoir if none were drawn off. It would probably be one hundred years before the loss of storage capacity would be seriously felt and it would become necessary to resort to methods of clearing it out.

At all times when the river is in flood the water in the reservoir will be more or less turbid. The lower the stage of the reservoir and the greater the flood in the river the greater will be the percentage of sediment held in suspension. The greatest amount of sediment will be at all times in the lower layers of water, and it will therefore contribute to the maintenance of the storage capacity to draw all waters from the lowest possible point at all times. Two outlets are provided in the form of tunnels, 10 by 13 feet, one around each end of the dam. It should be made an invariable rule that whenever water begins to run over the spillway the gates must be opened to full capacity—not only to draw off the maximum quantity of sediment, but also to reenforce the spillway capacity as much as possible.

Experience at the Sweetwater and other reservoirs shows that the greatest deposits of sediment are in the deepest parts of the reservoir, which in this case are near the dam. The above provision would dispose of a considerable portion of this, and any further provision for removing silt would be unnecessary for perhaps a century.

CEMENT MANUFACTURE.

The natural topographic conditions of this site are very favorable for the construction of a masonry dam, the most conservative and permanent design yet devised. This form of construction, however, is rendered very expensive by the remoteness of and difficulty of access to the site. There is a wagon haul of over 40 miles across mountainous country from the end of the railroad, which is a branch road, with light traffic and high rates. It is estimated that cement would cost at the dam site about $9 per barrel. As over 150,000 barrels of cement would be required for the dam, such a price is a most serious handicap to the project and presents a strong temptation to adopt a rock-fill type of structure, which would be immensely cheaper. However, before deciding this important point it was thought best to investigate the possibility of manufacturing cement in the vicinity, and search was made in Tonto Basin for materials suitable for the purpose. Eight samples of rock and clay were sent in for analysis to E. Duryee, superintendent of the cement works at Colton, Cal. The samples collected were as follows:

Sample No. 1.—Limestone near dam site. Very abundant and convenient.

Sample No. 2.—Calcareous shale near dam site. Ledge 1 foot thick. Expensive to quarry.

Sample No. 3.—Shale near dam site. Ledge 4 inches thick. Expensive to quarry.

Sample No. 4.—Clay 1 mile from dam site. Abundant.

Sample No. 5.—Shale near dam site. Ledge 3 inches thick. Expensive to quarry.

Sample No. 6.—Clay from Sallie May Canyon, 8 miles from dam site.

Sample No. 7.—Clay from hills 3 miles north of dam site. Very abundant.

Sample No. 8.—Shale from canyon below dam site. Ledge 2 feet thick.

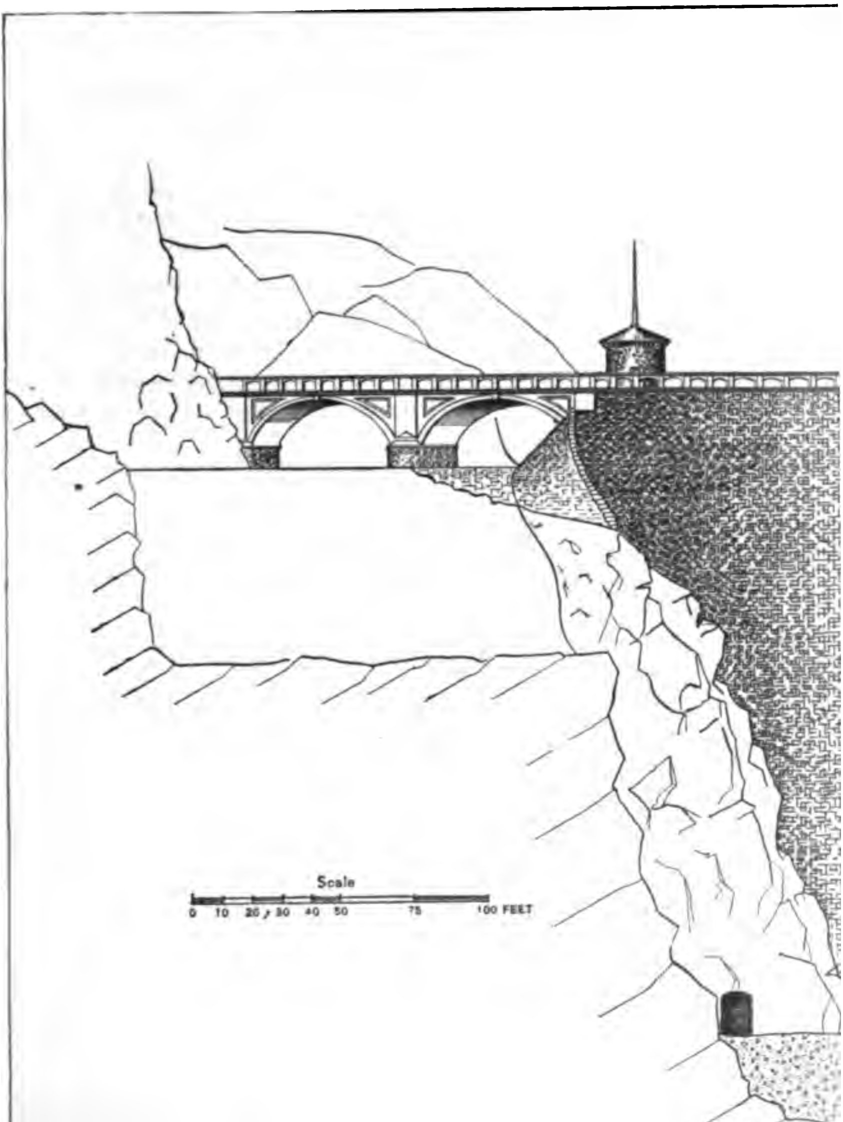
The shale, especially samples 3 and 5, being expensive to quarry and grind, was intended for use only in case the clays should, upon analysis, prove to be unsuitable for the purpose intended. The following analyses were reported by Mr. Duryee:

Analyses of clay from Tonto dam site.

Constituent.	No. 1.	No. 2.	No. 4.	No. 6.	No. 7.	No. 8.
Moisture	....	2.80	11.25	20.10	13.40	....
Silica	....	50.60	55.70	51.00	51.90	67.90
Alumina and ferric oxide	0.20	15.80	20.50	16.70	23.70	18.00
Magnesia	0.60	4.07	....	4.576	0.97	0.972
Calcium carbonate	95.80	16.60	11.80	6.048	10.90	0.00
Insoluble residue	3.30	....	....	....	....	....
Total	99.90	89.87	99.25	98.424	100.87	85.872

Everything considered, samples 1 and 7 appear to be the most favorable for the purpose, and accordingly a quantity of Nos. 1 and 7 were shipped to Colton for an experimental burn. The following is quoted from Mr. Duryee's report:

> The clay and limestone were ground separately and then mixed in the proportions of 6.18 pounds limestone and 2.25 pounds clay, making a raw mixture that tested 43 per cent lime. As the limestone was very hard and therefore more difficult to make into cement than a softer material, fluorspar to the amount of 1½ ounces, or 1 per cent, was added. The materials were also ground quite fine, but no finer than is the practice in some cement works, viz:
>
> *Fineness of raw mixture.*
>
> | | Per cent. |
> |---|---|
> | Passed a sieve of 50 meshes to the linear inch | 99.9 |
> | Passed a sieve of 100 meshes to the linear inch | 99.75 |
> | Passed a sieve of 200 meshes to the linear inch | 71.75 |
>
> The raw mixture was made into briquets and these, after being dried, were burned in a gasoline furnace. They burned to a good hard clinker of a good color, which yielded a cement of good appearance.


Scale
100 FEET

Analysis of the cement.

Lime	63.56
Alumina and ferric oxide	10.40
Silica	22.85
Magnesia	0.71
Alkalies not determined.	

Tensile tests of the neat cement briquets.

	Pounds per square inch.
7 days (1 day in air, six in water)	410
14 days (1 day in air, then in water until broken)	690
28 days (1 day in air, then in water until broken)	775

Chemical analyses of Nos. 1 and 7 were also made in the laboratory of the Geological Survey to test the uniformity of the deposits. These samples were found to differ slightly from those sent to Mr. Duryee, but still are eminently suitable for the purpose. The following are the results found in the Survey laboratory:

Analysis of limestone from Salt River, Arizona, made in the laboratory of the Geological Survey.

CaO	55.56
MgO	0.10
Fe_2O_3 and Al_2O_3	0.20
SiO_2	0.51
CO_2 (cal.)	43.77
	100.14

Analysis of clay from Salt River, Arizona.

Chlorine	0.20
Silica	50.51
Fe_2O_3	5.03
Al_2O_3 and P_2O_5	14.63
TiO_2	0.66
MnO	0.03
CaO	6.77
MgO	3.00
K_2O	3.06
Na_2O	2.18
Loss at red heat	13.30
	99.37

Altogether these results are gratifying, and prove beyond question the existence of convenient and abundant materials from which cement can be made. The greatest difficulty is the scarcity of fuel. There is a considerable quantity of wood in the reservoir site, mainly cottonwood and mesquite, which it will be desirable to clear out of the reservoir in any event. Wood is not suitable for burning cement clinker by modern methods, but if made into charcoal and then ground to powder would answer; or oil may be imported for the purpose from California.

The cost of the cement plant, with machinery capable of producing 300 barrels per day, is estimated by Mr. E. A. Duryee to be as follows:

Approximate cost of a rotary process, two-kiln Portland cement plant of a daily capacity of 200 barrels.

Crusher	$2,000
Mill for disintegrating clay	500
Rotary clay drier	1,500
Elevators and conveyers for raw materials	1,000
Storage bins for raw materials	1,000
Mills for grinding raw materials	10,000
Two rotary kiln linings and stacks	15,000
Mills for grinding cement	10,000
300-horsepower electric motors and step-down transformers	9,000
Conveyers and elevators for cement	1,500
Cost of grading and erecting machinery	10,000
Shafting and pulleys, belts, and setting up same	5,000
Buildings and bins for cement	10,000
Office, laboratory, and equipment of same	1,500
Freight	10,000
Plans, specifications, and superintendence	3,000
Total	91,000

With such a mill the cost of manufacture would be approximately as follows (allowing for power only the proportion necessary for maintaining and operating the electric plant provided):

Cost per barrel of making cement at Salt River dam site, Tonto Basin.

Labor and superintendence	$0.70
Raw materials	.30
Fuel for burning	.90
Power (maintenance and operation only)	.05
Repairs and sundries	.05
	2.00

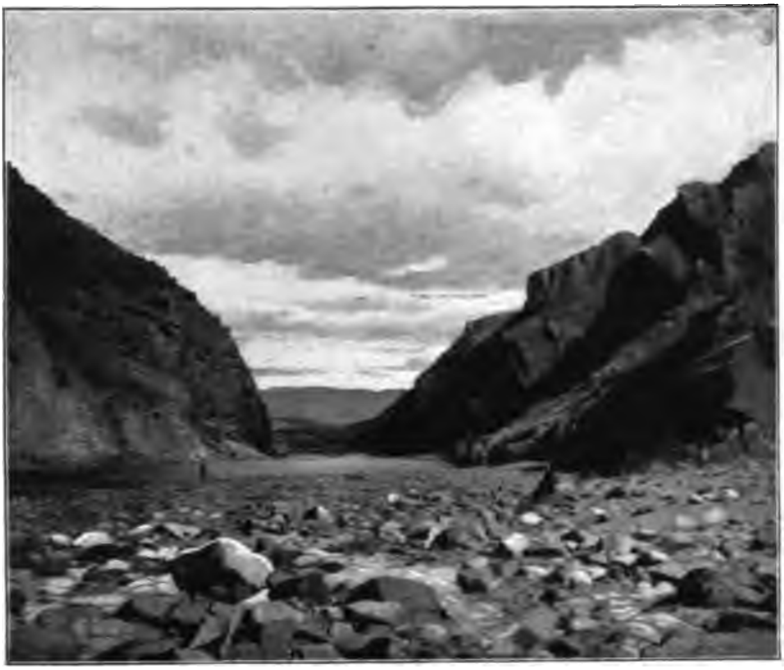
ESTIMATED COST OF DAM.

Estimated cost of Salt River storage dam.

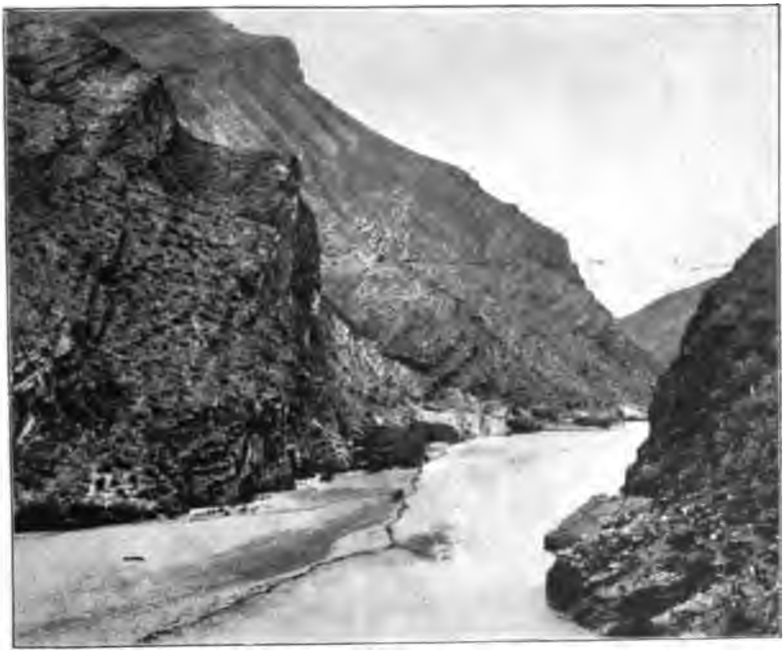
[247 feet above foundation; 190 feet available storage; capacity, 840,000 acre-feet.]

257,420 cubic yards rubble masonry, exclusive of power and cement, at $3.50	$900,970
Cement plant	91,000
Power plant, house, and canal	188,360
Manufacture of 150,000 barrels Portland cement, at $2	300,000
Excavation of foundation and river diversion	50,000
Outlet tunnels and lining	31,450
Gates and machinery	11,600
Outlet towers, shafts, and houses	9,000
Viaduct across spillways	26,000
Roads	15,000
Engineering and contingencies (15 per cent)	243,507
Total cost of structures	1,866,887
Damage to private lands	42,500
	1,909,387

Cost per acre-foot, $2.27.



A. SALT RIVER DAM SITE, LOOKING UPSTREAM.



B. SOUTH ABUTMENT OF PROPOSED SALT RIVER DAM, LOOKING DOWNSTREAM.

The cost of a dam 20 feet lower, storing 600,000 acre-feet, would be practically the same for all items except the masonry and cement, which would be about 20 per cent less, making the total cost about $1,680,000, or $2.75 per acre-foot capacity.

These estimates are based upon the data at hand, May, 1902, and are subject to modification.

CALIFORNIA.

In California, especially in the southern portion, irrigation has reached its highest stage of development, and the largest proportion of irrigable land has been brought under cultivation. There are, however, throughout the State, a number of rivers of large volume, whose waters are not completely utilized. Most of these have their

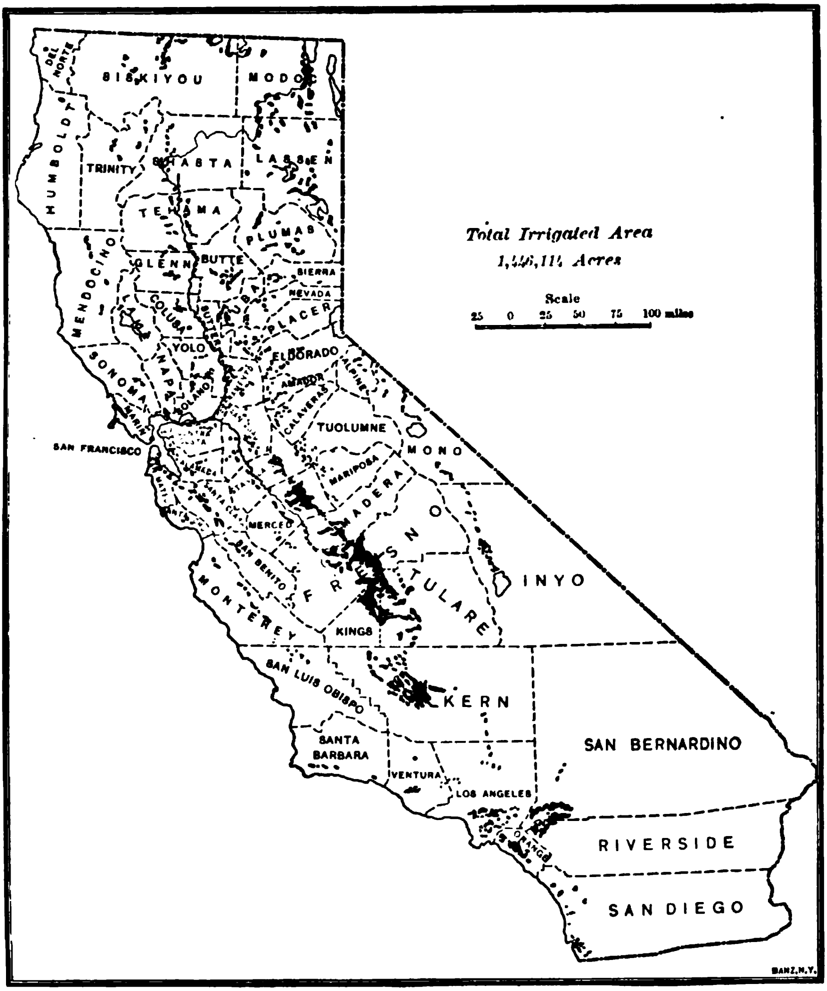


FIG. 13.—Map of irrigated areas in California.

sources in the mountains whose slopes have been included within the forest reserves. Reservoirs can be built on many of these and waters held for the reclamation of arid lands. The area of vacant land, by counties, on June 30, 1901, is given in the table below. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in California on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Alameda	....	....	488, 960	488, 960
Alpine	302, 978	98, 040	53, 382	454, 400
Amador	104, 561	42, 641	257, 278	404, 480
Butte	141, 355	....	921, 045	1, 062, 400
Calaveras	140, 863	38, 940	511, 397	691, 200
Colusa	34, 434	....	661, 886	696, 320
Contra Costa	9, 920	5, 960	450, 040	465, 920
Del Norte	431, 458	14	203, 408	634, 880
Eldorado	317, 544	337, 941	493, 955	1, 149, 440
Fresno	538, 485	1, 143, 140	2, 255, 655	3, 937, 280
Glenn	198, 336	....	614, 464	812, 800
Humboldt	517, 591	114, 899	1, 604, 950	2, 237, 440
Inyo	5, 797, 851	560, 000	230, 309	6, 588, 160
Kern	1, 327, 165	1, 098, 078	2, 726, 757	5, 152, 000
Kings	....	....	629, 760	629, 760
Lake	393, 252	....	456, 668	849, 920
Lassen	2, 330, 732	....	562, 068	2, 892, 800
Los Angeles	812, 773	521, 780	1, 354, 727	2, 689, 280
Madera	211, 794	454, 970	652, 916	1, 319, 680
Marin	13, 360	....	338, 000	351, 360
Mariposa	140, 282	355, 023	471, 095	966, 400
Mendocino	727, 291	47, 672	1, 545, 677	2, 320, 648
Merced	53, 210	....	1, 183, 270	1, 236, 480
Modoc	1, 829, 773	61, 064	503, 403	2, 394, 240
Mono	1, 531, 446	116, 120	285, 234	1, 932, 800
Monterey	1, 003, 281	....	1, 134, 319	2, 137, 600
Napa	114, 318	....	384, 882	499, 200
Nevada	108, 941	294, 500	218, 639	622, 080
Orange	30, 643	57, 951	391, 406	480, 000
Placer	47, 887	498, 683	327, 030	873, 600
Plumas	1, 230, 102	640	493, 418	1, 724, 160
Riverside	2, 632, 470	1, 369, 740	684, 510	4, 686, 720
Sacramento	15, 585	110, 665	513, 750	640, 000

Unappropriated, reserved, and appropriated lands in California, etc.—Continued.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
San Benito	380,030		508,290	888,320
San Bernardino	7,951,486	4,104,502	710,092	12,766,080
San Diego	3,355,474	696,034	1,374,412	5,425,920
San Francisco			30,080	30,080
San Joaquin		1,150	892,290	893,440
San Luis Obispo	607,067	924	1,510,409	2,118,400
San Mateo			277,760	277,760
Santa Barbara	127,546	677,863	879,071	1,684,480
Santa Clara	90	1,945	821,005	823,040
Santa Cruz			271,360	271,360
Shasta	662,895	63,448	1,754,297	2,480,640
Sierra	368,452	136,255	109,693	614,400
Siskiyou	2,141,910	47,374	1,644,956	3,834,240
Solano	146,382	7,160	422,458	576,000
Sonoma	164,479		872,321	1,036,800
Stanislaus	104,572		827,268	931,840
Sutter		8,858	389,222	398,080
Tehama	862,281		1,062,839	1,925,120
Trinity	1,544,080	47,730	508,670	2,100,480
Tulare	134,536	1,643,089	1,391,655	3,169,280
Tuolumne	94,791	801,831	516,498	1,413,120
Ventura	118,389	487,723	495,328	1,101,440
Yolo	33,844	1,902	601,676	637,440
Yuba	63,264	7,403	336,373	407,040
Total	41,951,249	16,063,670	41,812,281	99,827,200

RECLAIMABLE LANDS.

The areas to be benefited by the stored waters are, as a rule, in private ownership. While nearly one-half of the area of California consists of vacant public land, most of this is in the eastern or southeastern part of the State, and consists of broad deserts, such as that known as the Mohave Desert. There are in the northern end of the State some lands still belonging to the Government which may be ultimately reclaimed; but, as a rule, it may be said that the construction of reclamation works in California will benefit primarily lands in private ownership.

The principal exceptions to the above statement are the lands along Colorado River, in the extreme southeastern part of the State. This river has an estimated flow during the summer of from 4,000 to 10,000 cubic feet per second. It rises in flood in summer to 70,000 cubic feet per second, or several times this, and carries a large amount of sediment in suspension. The valleys along the river are relatively narrow, but at one point or another water might be taken out to irrigate many thousand acres of land. The serious difficulties of successfully taking out irrigation ditches arise from the low gradient of the river and the large quantity of mud deposited in the canals.

As preliminary to reclamation work in California, measurements of the principal rivers have been made, particularly the low-water flow of important streams coming from the forest reserves. These observations should be conducted for several years, in order to afford data upon which to base any proposed storage system. It is possible that ultimately some favorable arrangement can be made with the owners of arid lands by which the letter and spirit of the reclamation law can be fulfilled in making homes for settlers.

COLORADO RIVER DIVERSION.

The first definite work being undertaken in California looking toward the reclamation of arid lands is that along Colorado River. A reconnaissance of this stream has been made by Mr. J. B. Lippincott from a point beginning at Hualapai Wash, in Arizona, through Boulder, Black, and Pyramid canyons, which lie along the portion of the stream which forms the boundary between Arizona and Nevada. Here were found a number of points where dams might be built and water power developed for use in industrial purposes and for pumping water from the river to the adjacent mesas. The first open valley of any considerable importance is that near Camp Mohave. Below this locality there are a number of valleys on each side of the river, interrupted by mountain spurs or hills approaching the stream.

The preliminary reconnaissances made by Mr. Lippincott, and also by Mr. Arthur P. Davis, indicate that irrigation is possible, but it is not apparent whether it will be feasible to build high or low dams across the river in order to raise the water and divert it into canals. Careful surveys must be made to determine the cost of various projects which appear feasible. These surveys have been begun, and, with the cooperation of the Topographic Branch of the Geological Survey, contour maps are being made along the river, from which the best positions for large canals can be readily determined.

Preliminary to undertaking work along Colorado River, lands were temporarily withdrawn from entry under the terms of the reclamation law. The location of these is shown on the accompanying sketch, fig. 14.

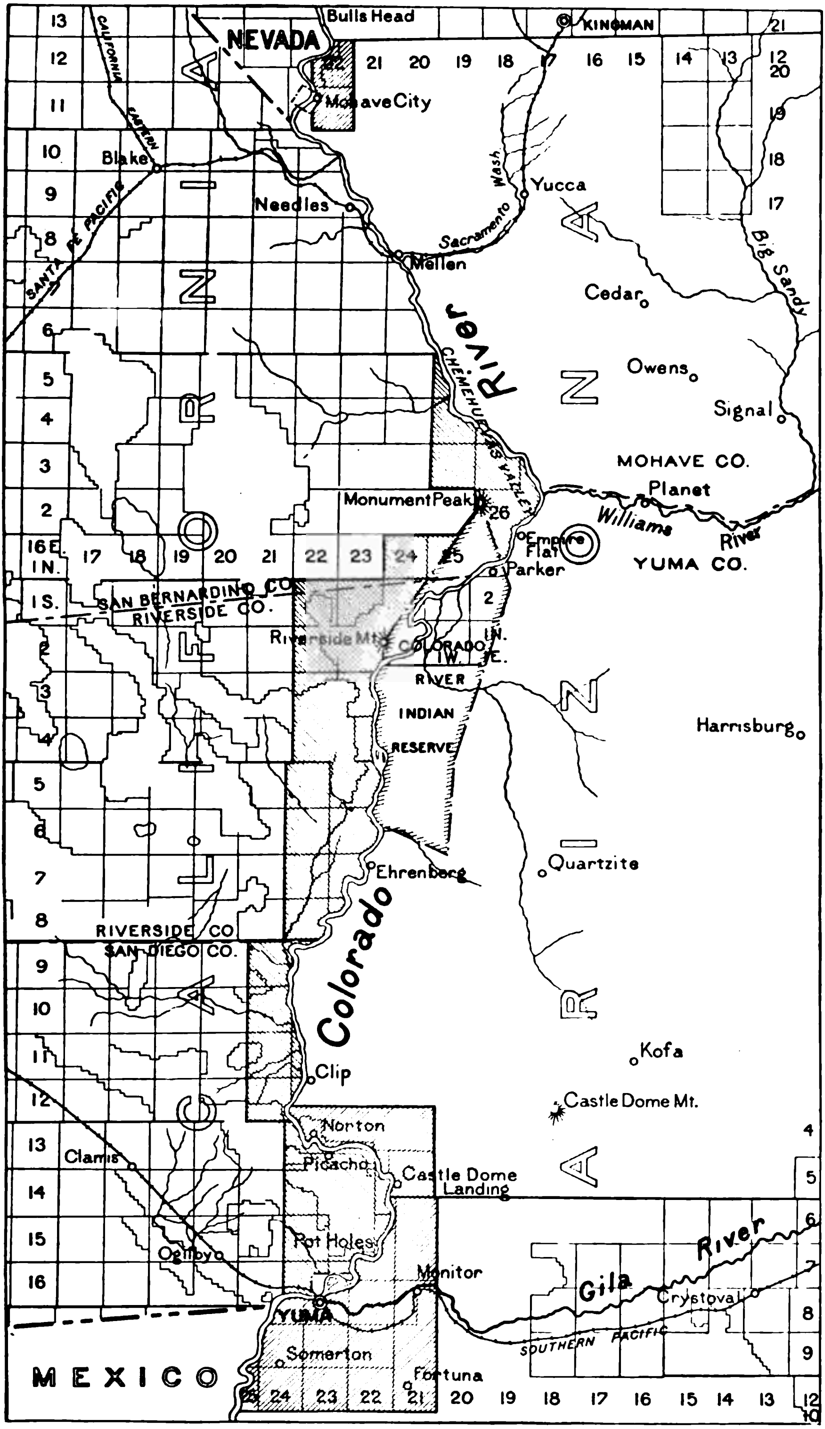


FIG. 14.—Map of lands temporarily withdrawn along Colorado River in California and Arizona. (Additional lands have been reserved since this map was drawn.)

RECONNAISSANCE OF COLORADO RIVER ABOVE NEEDLES, CAL.[a]

A reconnaissance of the upper portion of Colorado River was made by Mr. Lippincott. This was carried out rapidly, as he left Los Angeles October 6, 1902, and returned on October 16. His observations extended from a point known as Gregg's ferry, Mohave County, Ariz., to the town of Needles, Cal. A description of the river below this point is given in another report by Mr. Lippincott, abstracts from which are shown on a following page. The report of this reconnaissance of the upper river is made largely in the form of a memorandum compiled during the trip. All of the distances and areas are from estimates without survey. The trip was begun near the Walapai dam site, which is situated at the point where Walapai Wash discharges into Colorado River. The canyon at this point boxes up for a distance of about 700 feet, and has a prevailing width of from 275 to 300 feet. It is believed that bed rock is extensively covered with detritus at this point. The dam would necessarily be an overflow structure, as there is no opportunity for spillway at this point. The walls of the canyon are porphyry, and are badly shattered. Ledges of quartz and harder material run throughout the mass in varying directions. High-water marks at the upper end of the dam site were noted 25 feet above the present low-water stage of the river, and at the lower end of the gorge 19 feet above the present stage. The river has a rather flat grade above the site for several miles. A wagon road comes to the dam site.

The Gregg or Scanlon ferry is operated by William Gregg, of Hackberry. There is a small farm here, raising vegetables, etc. This is about 3 miles above the Walapai dam site. The road from White Hills and Hackberry goes to Gregg's ferry and the dam site. The distance from Chloride to the ferry is 60 miles, and is approximately the same from Hackberry. There are a store and a blacksmith shop at Hackberry and a store at Chloride. At the time of inspection, October, 1902, there were 4,000 second-feet of water in the river.

The trip was made in a boat 14 feet long, 3 feet beam, with flat bottom and square ends, built at White Hills, of rough Arizona pine; the sides were 16 inches high, and it drew 6 inches of water. The boat was too small, and it should have had a pointed bow for rowing, as it is desirable to row almost continually, especially in the rapids, in order to gain headway for steering.

The start was made down the river from the Walapai dam site at Gregg's ferry. Below this point there is a long rapid, with waves running from 2 to 3 feet high at the present low stage of the river. The boat fouled on a rock in the first 100 yards and had to be unloaded and calked. Starting again, a very interesting ride was had through this first rapid, which was by far the most vigorous encountered the first day. Below this the party passed through about 8 miles of box canyon, the rock being porphyry and the canyon ranging from 300 to 500 feet wide at water line. After traversing a distance of 8 miles the Senator mill was reached, 10 stamps being in operation at this point.

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[a] From report by J. B. Lippincott.

The valley through which the river ran on the second day's trip was open and the side walls were of soft sandstone and volcanic conglomerate. It is 6 miles from Senator mill to the Temple Bar mill. Just above the Temple Bar mill there is a very prominent and beautiful sandstone butte on the right bank. From Temple Bar to Rioville the distance is about 12 miles. Here the Virgen joins the Colorado and the stage line from Chloride, Ariz., to St. Thomas and St. George, Nev., crosses the river by a ferry. Mr. Daniel Bonilla lives here and has a farm on which he raises hay, etc. He maintains a Weather Bureau station, and says that the rainfall for the last year was 0.22 inch. The distance from Chloride to Rioville is 65 miles by wagon road. Freight from Chloride is $20 a ton. The trip was continued this day to the head of Boulder Rapids, about 3 miles below. A series of small rapids was passed, not dangerous, but some of them shallow.

The third day the party traveled over a series of small riffles to the entrance of the narrow box canyon known as Boulder Canyon. Near the upper end the canyon is 215 feet wide, and a sounding showed 14 feet of water. The rock of the canyon is granite, in large, true ledges. The sides of the canyon are very steep, having a depth of 60° on the right bank and 75° on the left bank. This box canyon is about half a mile long, with widths varying from 240 to 300 feet and cliffs as described above. Depth of water varies from 14 to 40 feet. This is the best dam site that was observed during the trip down the river, both as to the narrowness of the river and the availability of large quantities of rock for use in a dam. A wagon road comes within 10 or 12 miles of the dam site. The combined valleys of the Virgen and Colorado rivers, though narrow, offer considerable opportunity for storage because of their flat grades. This site is deemed worthy of survey.

Below the box about half a mile there is a long rapid that is rather rough, and numerous rocks are in the channel, making it bad for a boat in low water. As many as six bowlders were struck by the boat in running this rapid. The remaining part of Boulder Canyon to Old Callville was traversed without any events of interest. The canyon widens after passing the first box and offers no opportunity for dam sites. From Callville Wash to Las Vegas Wash, and for 3 miles beyond, the river passes through a narrow valley.

On the fourth day a series of small rapids was passed for about 2 miles below Las Vegas Wash, when Black Canyon was entered. This is named from the black porphyry walls which rise abruptly from the water's edge a thousand or more feet, offering little footing on the sides. The width of this canyon at the water's edge ranges from 250 to 500 feet. At the lower end of the box is a dam site. The width of the water level is estimated at 300 feet; the cliffs are steep. Emerging from this box the hills continue to rise from near the water's edge, but not so steeply. Numerous dam sites could be located in Black Canyon.

The valley formed by the junction of the Las Vegas Wash with the Colorado offers another possible reservoir site that should be surveyed, though it is quite probable that backwater from the lower dam, if it were built, would reach the upper site, even though it were of quite moderate height.

There is one strong rapid near the center of Black Canyon, but no rocks were encountered therein. The canyon proper is about 20 miles long. The river remains in canyons more or less abrupt and narrow until within a mile of Eldorado.

On the fifth day Eldorado, Nev., was reached, early in the morning. Below Eldorado the party passed for 18 miles through a narrow valley with bordering gravel hills and a small amount of bottom lands suitable for agriculture. The river then flows through a short canyon, about 600 or 800 feet wide, with rock sides, a feature of which is a ledge of rock projecting above the water level at four or five places across the channel. This offers a suitable site apparently for a low dam 15 feet high. Below this canyon Cottonwood Valley opens, and the Quartette mill is near its head.

At Hampton's ranch are about 40 acres under irrigation, in alfalfa and vegetables. These are sold to the miners at high prices. It is stated that about 10 tons of alfalfa to the acre are cut annually. The water is raised by a water wheel to the top of the bluff. There are about 5,000 acres of agricultural land in Cottonwood Valley that possibly could be reclaimed by means of a canal diverting part of the river at the narrows previously mentioned, about the Quartette mill, or by pumping plants. No indication of alkali was observed in the soil. At the lower end of Cottonwood Valley are narrows with low granite sides. The river is possibly 600 feet wide at this point, and it offers an opportunity for diversion. Below this point, however, the valley is narrow, with poor sides for canal construction, for 8 miles. The river has few rapids or riffles below Cottonwood Island.

Passing by Sheep Trail mill, the next point of interest is Bulls Head, a broad granite canyon at the head of Mohave Valley. Near the lower end of the canyon, where a low double-pointed peak projects into the left bank, the canyon is perhaps 600 to 700 feet wide. This is probably the best irrigation diversion point for Mohave Valley, which lies just below. From the narrows to Hardyville the valley is nearly all on the Arizona side. There are a number of new buildings and a new mill below Hardyville. A rather large valley opens on the Arizona side below Hardyville, but there is little valley land on the Nevada side.

At Mohave Indian School is a post trader with a small stock of goods. The valley is irregular, and above Camp Mohave is on the average 0.7 of a mile wide, and contains about 10,000 acres of bottom land. Below Camp Mohave the valley broadens, and there is an average width of perhaps 5 miles to the Needles bridge, a distance of about 15 miles. There probably are from 40,000 to 50,000 acres in the bottom below Camp Mohave. The land is flat, and crops planted at Hamptons and Camp Mohave indicate the adaptability of the land to sweet potatoes, alfalfa, grain, etc.

Interesting features on the river are the jetties for training the river between Eldorado and Bulls Head. These consist of bowlders piled 3 to 6 feet high on a natural slope diagonally downstream and partly across the channel. In this way the river is partially prevented from dividing into side channels and made to concentrate on bars and deepen itself. Silt is deposited above the jetties, level with the top. These were placed by the army engineers probably ten years ago. They are still doing some service.

The water is pumped from the river at Camp Mohave, by means of a centrifugal pump, into an irrigation ditch, for the use of the school farm. This ditch apparently has a good grade, for it is free from silt and has been used for several years. It is in marked contrast with the ditch at Hamptons, which apparently has too flat a grade and is pretty badly silted. It is believed that in the low stages of the river the prevailing velocity of the channel in its steeper portions is apparently 3 to 4 feet per second.

Distances by wagon road.

	Miles.
Chloride to Walapai dam site	60
Chloride to Rioville, Nev	65
Hackberry to Walapai dam site	55
Rioville to White Hills	25

Distances by river. [a]

	Hours travel.	Miles.
Gregg's ferry to Walapai Wash		3
Walapai Wash to Senator mill	2.5	10
Senator mill to Temple Bar mill	2.0	7
Temple Bar mill to Rioville, Nev	4.0	13
Rioville to head of Boulder Rapids at mouth of Sacramento Wash	1.0	3
Generally accepted distance from—		
Rioville to Eldorado		90
Eldorado to Needles		90
Rioville to Needles		180

[a] River distances estimated. The time is given for constant rowing with square-end boat at low stage of river. Wind prevailed upstream during trip.

Distances by river—Continued.

	Hours travel.	Miles.
Rioville to Boulder Canyon dam site		11
Mouth of Sacramento (wagon road) to Boulder Canyon dam site.	2.0	8
Sacramento Wash to Old Callville	4.5	18
Rioville to Old Callville	5.5	21
Old Callville to Las Vegas Wash	2.0	6
Las Vegas Wash to Camp 3	.5	2
Black Canyon, length of	5.0	20
From 7 a. m. to 5 p. m	10.0	40
Rioville to Eldorado	29.5	74
Eldorado to Gold Bug	2.0	10
Eldorado to Quartette mill	6.5	25
Eldorado to Hamptons, Camp 6	8.0	28
Hamptons to Sheep Trail mill	4.5	20
Hamptons to Bulls Head	6.0	26
Quartette to Bulls Head		34
Bulls Head to Hardyville	1.7	7
Hamptons to Camp	9.5	43
Camp to Mohave	.75	3
Eldorado to Mohave	18.25	73
Bulls Head to Mohave		20
Mohave to Needles	4.75	20

The reconnaissance above described supplemented knowledge of the river which had been obtained at an earlier date. It cast light upon the situation and made possible the consideration of some of the until then unknown features of the utilization of this great river. On the following pages is given a description of the river below Needles, being an account of a trip made by hydrographers of the Geological Survey, who had been instructed to report upon the practicability of diverting any or a part of the waters of Colorado River.

RECONNAISSANCE OF COLORADO RIVER BELOW NEEDLES, CAL.[a]

On December 29, 1901, a party consisting of J. B. Lippincott and Jeremiah Ahern, hydrographers, and W. B. Clapp and F. M. Barnes, field assistants, started on a reconnaissance of Lower Colorado River between Needles and Yuma. They were provided with a boat 20 feet long, square cut at each end, having 5 feet beam, and drawing 8 inches of water. It was rigged with a sail, which was found to be very serviceable, and was provided with two pairs of oars. The prevailing

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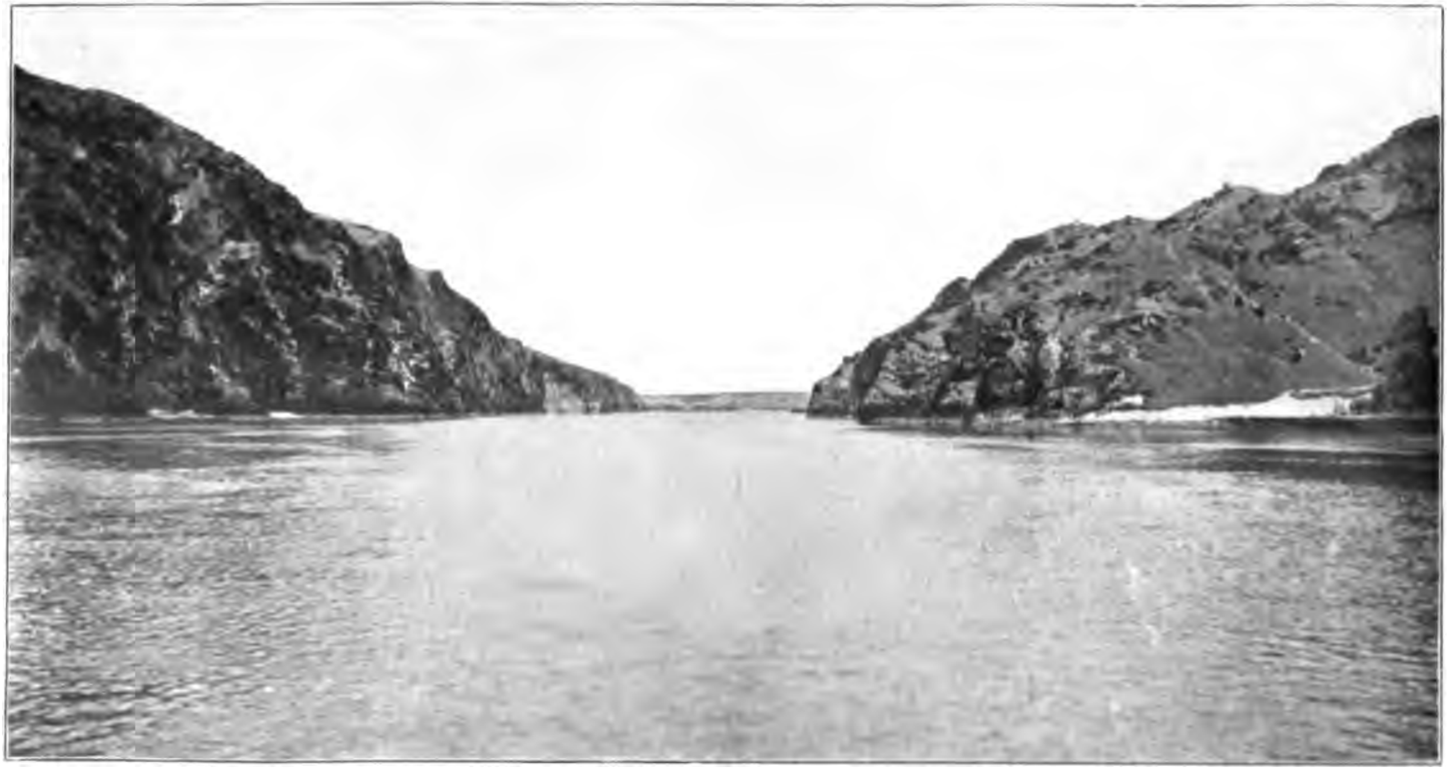
[a] From report of J. B. Lippincott and Jeremiah Ahern.



BLUE CANYON DAM SITE 2 MILES BELOW NEEDLES ARIZ

direction of the winds on this river in the winter and fall is downstream, while in the summer it is upstream. Owing to the swift currents, it is difficult traveling upstream with a small boat. A light-draft boat is essential, particularly during low stages of the river, as many shoals and sand bars exist in the channel. The journey from Needles to Yuma was made in eleven days, or at an average rate of a little less than 27 miles a day. Many intermediate stops were made for the purpose of observations, and numerous hills and bluffs along the river were climbed to obtain better views of the topography. The instruments used on the trip were aneroids, field glasses, hand levels, and hand compasses. All distances and areas given in this report are estimated.

The elevation at Needles railroad station is 474 feet, that of the river opposite being about 450 feet. The elevation of the river at Yuma is 107 feet. It therefore has a fall of 343 feet in an estimated distance of 291 miles, or 1.18 feet to the mile. It was quickly recognized that aneroid observations on a stream of so light grade are of small value in comparing relative heights. The straight-line distance from Yuma to Needles is 147 miles, half the distance by river. The latter distance is largely made up by the meanderings of the stream in the alluvial valleys which prevail throughout a large portion of its course. Consequently diversion canals having relatively straight alignments would have an available fall of about 2 feet to the mile.

RESERVOIR SITES.

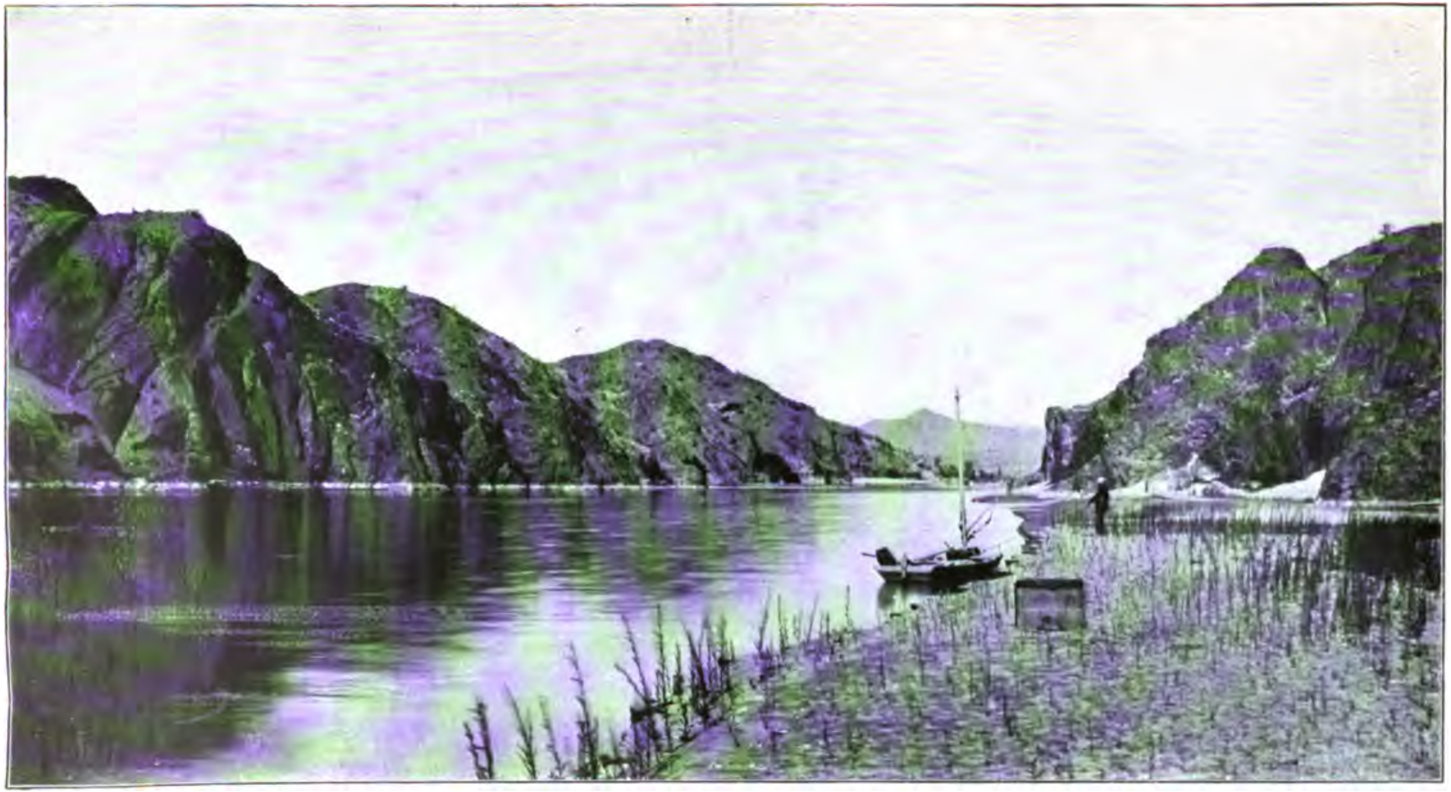
There is a long river flat, generally known as Mohave Valley, averaging 3 miles in width on the Arizona side and three-fourths of a mile on the California side, containing 50,000 acres, beginning, it is stated, 10 miles above Camp Mohave, at a point known as Bulls Head, and extending to Needles, a distance of about 30 miles. This is good bottom land and is in large part above high water. The upper end of the valley was not visited, but it is probable that diversions from the river at Bulls Head would command these lands. At Bulls Head the river, it is stated, is 600 feet wide, with steep granite sides.

At Needles the mountains on either side rise to heights of several thousand feet, offering no opportunities for extensive diversions. The river at the Needles Bridge, at Mellen, Ariz., was examined as a possible site for a gaging station, and it was observed that at the present low-water stage the channel is irregular and diagonal. The bridge is 80 feet above the water and would make a poor station.

Two miles below the bridge the river enters the Blue Canyon and is contracted to a width of 400 feet. (See Pl. XIX.) The side walls are of granite, greatly shattered on the surface. If a dam 100 feet high were placed here, the water impounded would cover the large flat above Needles. The Santa Fe Railroad crosses the river at Mellen on an imposing cantilever bridge 80 feet above the surface of the stream. A dam 100 feet high at Blue Canyon would raise the water above the floor of this bridge and would inundate the town of Needles. Spillway opportunities exist on the left bank 100 feet above the present level of the river. A great reservoir would be created by the construction of this dam. No surveys of this site were made, but it is probable that a dam 100 feet high would give a reservoir capacity of more than 1,500,000 acre-feet. A dam 40 feet high would probably create a reservoir 20 miles long, flooding 40,000 acres of land and impounding 500,000 acre-feet of water. The floods on the river come in May and June and would fill this reservoir by the 1st of July; therefore the water would not necessarily be retained therein more than four months, and the loss by evaporation should not exceed 4 feet in depth. In view of the existence of several reservoir sites below and of the damage which would occur from the construction of a dam at Blue Canyon, it is believed that this valley near Needles can be more profitably utilized by irrigation from diversion canals.

Below the Blue Canyon dam site for 15 miles the river is in canyon, passing through, first, Blue Canyon and then Red Canyon. A monument-like rock about 30 feet in height, called Mohave Rock, occurs on the left bank of the river at the lower end of Red Canyon. Here the canyon opens into Chemehuevis Valley, which extends a distance of 20 miles, or to within 15 miles of Williams River. This valley has a maximum width of 5 miles and offers a good site for a large reservoir. No opportunity is seen to present itself for extensive interior diversion above this point, the grade to the valley being very slight and the sides rising rapidly beyond the alluvial plain. The area of Chemehuevis Valley is 20,000 acres. The valley is occupied by a few families of Chemehuevi Indians. They raise some stock, but no cultivated fields were observed. Below Chemehuevis Valley there is a valley averaging a mile in width and about 17 miles in length, and ending at the junction of Williams River with Colorado River. The grade of the river through this narrow valley is slight.

Williams River was flowing 4 second-feet of water on January 1, 1902. The valley of this tributary near its mouth is a mile wide and is flat, so far as could be observed with a hand level. A half mile below the mouth of this tributary there is a dam site. (See Pl. XX.) The width of the stream at the water level was found to be 410 feet. A dam 60 feet high would back the water about 40 miles, with an average width of 1 mile, covering 40 square miles of Colorado Valley proper. No opportunity of observing the extent of the basin up Williams River was had, but it is believed that at least 10 square miles more should be added for this tributary. Using an average depth for the reservoir of one-third the height of the dam, with a 60-foot dam this would give a reservoir capacity of 640,000 acre-feet. The sides of



DAM SITE ON COLORADO RIVER BELOW MOUTH OF WILLIAMS RIVER.

the canyon are granite, and rise to heights of several hundred feet. The slope of the abutments on the right bank is 45° to an elevation of 160 feet above the bed of the stream, beyond which the slope is about 10°. On the left bank the abutment walls rise at an angle of 45° to an elevation of 150 feet, beyond which the slope is flatter. There are no cultivated lands or other improvements in the basin of the reservoir site, except one Huntington mill on the right bank about 10 miles above the dam site and a small patch of irrigated land on the left bank just above Williams River. A number of mining claims probably would be found to lie within the reservoir site.

The distance from Williams River to Empire Flat is 14 miles, and from Empire Flat to Parker, the agency for the Colorado Indian Reservation, it is 15 miles. From Empire Flat to Parker the river is in a narrow valley possessing little irrigable land. The sides of this valley consist of rising mesa lands greatly dissected by arroyos. The construction of a canal at high elevations on either side of the river would be expensive. The Colorado Indian Reservation extends from Monument Peak to within 6 miles of Ehrenberg. The distance from the agency at Parker to Ehrenberg is 59 miles. The bottom lands are almost entirely on the Arizona side of the river, and between Parker and Ehrenberg they lie almost wholly within the Indian reservation. There are said to be three or four hundred Indians located here, but no agricultural developments of any magnitude were noticed. At a projecting point on the Arizona side 1½ miles above Parker, and favorable for a diversion, there is a tunnel, located so as to divert irrigation water for the agency, but its intake, which was in soft rock, was destroyed by the high velocities of the water. A few feeble attempts at irrigation were observed near the pumping plant. On the right bank at this diversion point the land is low for one-fourth of a mile, the distance not being definitely determined. Beyond this low plain, on the right, gravel hills rise from 75 to 100 feet above the river bottom. A wooden weir, such as is used on Kern River, California, raising the low water from 10 to 15 feet, would command a good tunnel diversion site, and such a canal would command the entire flat between Parker and Ehrenberg. A wagon road is now being constructed from Needles to Parker, a distance of 70 miles. Water can be had at a halfway point known as West Wells.

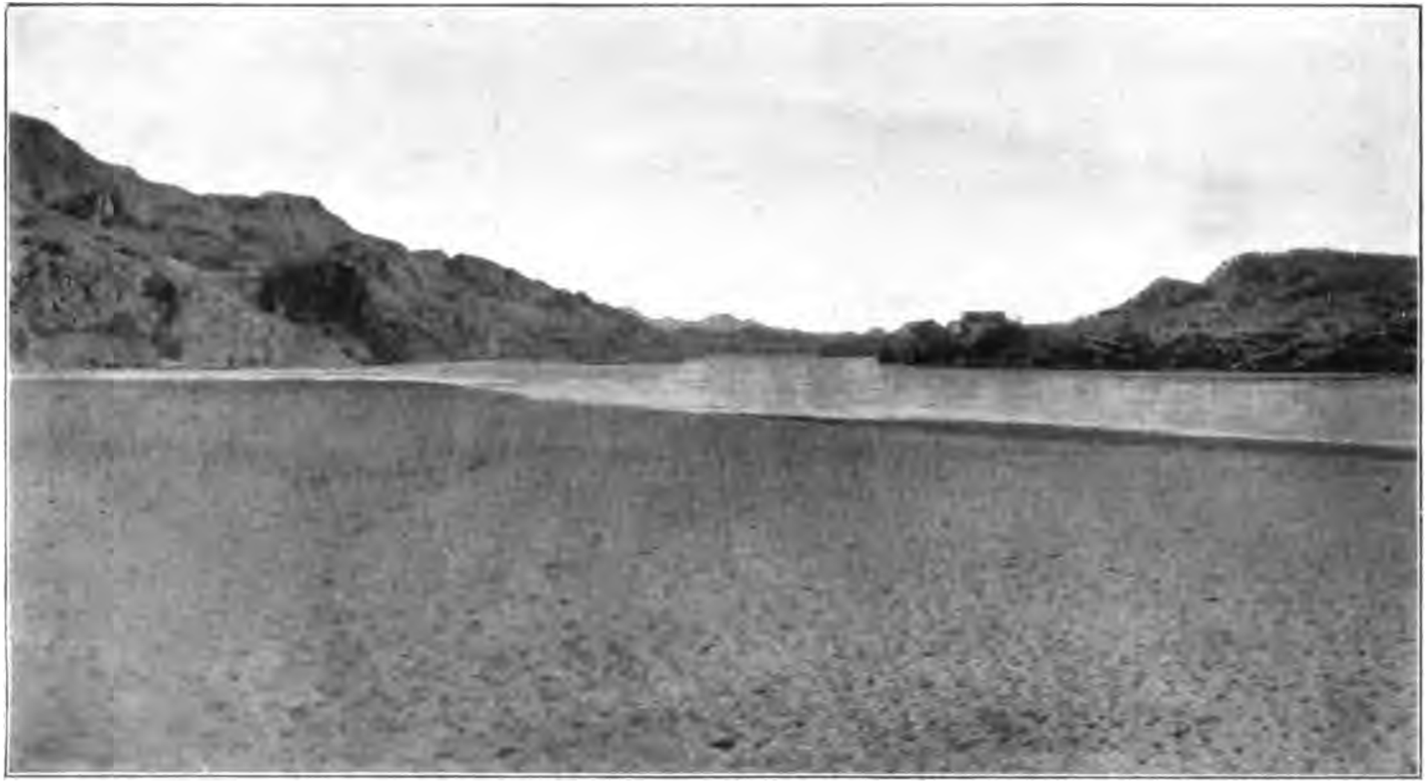
A prominent peak, known as Riverside Mountain, is 20 miles by river below Parker and 12 miles in a straight line. It is a corner of the reservation. The valley is 8 miles wide near Riverside Mountain, eight-tenths of which is on the Arizona side.

Twenty-seven miles below Riverside Mountain, on the right bank, is a point of black rocks, where the valley on the Arizona side is 4 miles wide. Below, on the California side, the foothills recede, offering a good site for diversion headworks, though the bottoms on the left bank are low and wide. The channel seems to naturally encroach upon the right bank. Below, on the Arizona side, the valley continues 12 miles wide to a place where the low, gravel, mesa-like hills approach the river above Ehrenberg. This valley between Parker and Ehrenberg is 45 miles long and 5 miles wide in Arizona, and contains 220 square miles, or about 140,000 acres, all of which could be put under an irrigation canal diverting water from above Parker, as previously noted. There is sufficient additional bottom land in the reservation in California to bring the total area of bottom land to 200,000 acres. The valley on the California side, beginning at the Black Rocks 12 miles north of Ehrenberg, quickly attains a width of 5 miles, and at Ehrenberg is from 10 to 12 miles broad. The Blythe estate has obtained title to 42,000 acres of the north end of this California valley, and is using it for a stock ranch. Private surveys are now being made for the reclamation of some of this land. This great valley, called by Lieutenant Ives the Great Colorado Valley, is undeveloped and is little used, even for stock raising. Ehrenberg, containing half a dozen adobe houses, is the only settlement between Needles and Picacho, a distance of 241 miles by river. Six miles south of Ehrenberg, where a gravel hill 200 feet high projects into the left bank of the river, observations were made and a number of photographs were taken.

The valley on the California side is 10 miles wide, and extends southward from the Black Rocks 12 miles above Ehrenberg as far as the big bend of the river near Picacho, Cal. On the Arizona side, below the point of observation noted above, the valley again opens and maintains a width of 2 miles as far as could be observed to the south, but looks very low. All of these valleys along the river are bordered by low, mesa-like, river-gravel hills from 100 to 200 feet high, back of which, at varying distances, rise the mountains. The valley lands on the Arizona side maintain a width approximating 5 miles from the hills 2 miles below Ehrenberg to the big bend of the river near Picacho. From a point 6 miles north of Ehrenberg to the big eastern bend of the river the bottom lands will average on the two sides of the river 6 miles in width by 40 miles in length, including about 150,000 acres. Through these bottoms the river meanders, overflowing its banks during stages of high water.

The reconnaissance was continued down the river to Picacho, no points offering opportunity for extensive interior diversions being noted until the river finally leaves the last of its mountain canyons, 10 or 15 miles below the town.

About 20 miles above Picacho the river encroaches on bold, rocky bluffs on the right bank, but the bottoms are about a mile wide on the left side. The aneroids indicate an elevation of 247 feet at this point. The river here starts its big bend to the east. These are the first rocky



DAM SITE ON COLORADO RIVER NEAR NORTON, ARIZ.

banks encountered below Ehrenberg. If a long tunnel diversion from the river is to be made toward the Salton Desert in California, it probably could best be made here, but from the data now available this is not believed to be feasible, as it would probably require a tunnel fully 20 miles in length. One mile below the rocky cliffs mentioned, at a place called Norton, on the Land Office map of Arizona, the river runs between porphyry hills. The rock comes down to the water's edge on the east side of the river, but the distance between the walls is fully 1,800 feet. Spillways on the side are available. Diversion lines on either side of the canyon would be expensive and difficult, and the site does not seem to be suitable for a cheap dam. (See Pl. XXI.)

Two and a half miles below Picacho the river again passes through cliffs of porphyry. This canyon is referred to by Lieutenant Ives as Canebrake Canyon. The rocks rise abruptly on the west bank, and have a slope of about 6 horizontal to 1 vertical on the right bank. The distance between the walls at the water level is approximately 700 feet. Spillway opportunities exist on the California side. The rock is of a hard, brecciated variety. This is the last canyon on Colorado River. It is a dam site of considerable merit, and probably the most available for extended diversions of the lower river to the east and west of Yuma. It is the best initial point for surveys to ascertain irrigable areas.

It is believed that the water supply of the Lower Colorado is normally greater than would be required to cover all areas irrigable from it in the United States.

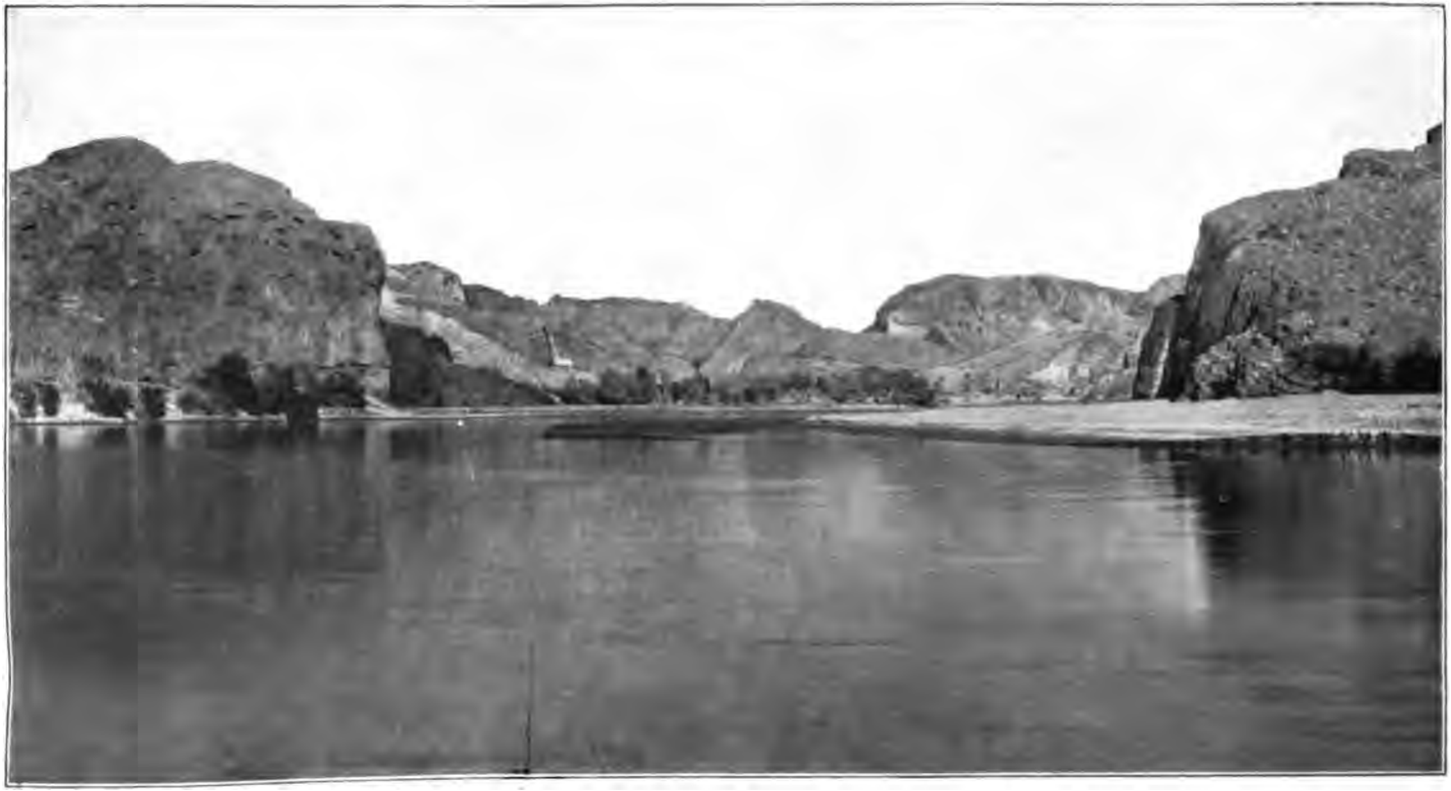
Twenty miles above Yuma, on the Arizona side, is a valley of about 5 square miles. Small valleys continue intermittently until the valley of Gila River is reached, a few miles above Yuma, on the Arizona side, and the lands of the Yuma Indian Reservation are encountered on the California side. A point known as the Pot Holes, about 14 miles above Yuma, which frequently has been referred to by others as a suitable diversion point, consists of low, granitic mountains on the right bank and of low buttes on the left bank. The distance between these rocky walls is at least 6,000 feet, and the river is now within the center of this opening, though old channels indicate that at a recent period it was close to the California side. The situation does not seem well suited for diversion purposes.

Below the Pot Holes and above Yuma no more mountains were observed near the river, but the low, gravel-covered mesas border the bottoms at varying distances. These mesas are stony or sandy on the surface, but the soil improves a few inches below the top. Near the river they are greatly eroded with cross-drainage lines. Below the Pot Holes broad drainage lines open out on either side, and above

Yuma they contain probably 40,000 to 80,000 acres of high-grade lands. A large area of mesa land about 100 feet in elevation above the river extends southeasterly from Yuma.

Estimated distances, by river, of Colorado River reconnaissance.

	Distance between points.	Distance from Needles.
	Miles.	*Miles.*
Needles to Camp No. 1	....	17
Needles to the Needles Bridge	....	18
The Needles Bridge to Williams River	46	....
Needles to Williams River	....	64
Needles to Camp No. 2	....	37
The Needles Bridge to Blue Canyon	3	....
Blue and Red canyons	15	....
Chemehuevis Valley	20	....
Needles to Camp No. 3	....	54
Needles to Camp No. 4	....	75
Williams River to dam site below	½	....
Williams River to Empire Flat	14	....
Williams River to Parker Agency	29	....
Empire Flat to Parker Agency	15	....
Needles to Parker Agency	....	93
Needles to Parker Agency (by road)	....	70
Needles to Parker Agency (authority agent)	....	100
Parker to Riverside Mountain	20	....
Blythe headworks to Ehrenberg	12	....
Blythe headworks to Riverside Mountain	27	....
Parker to Ehrenberg	59	....
Needles to Ehrenberg	....	152
Needles to Ehrenberg (general statement)	....	170
Needles to Big Bend	....	221
Colorado Valley, length	120	....
Needles to Picacho	....	241
Ehrenberg to Picacho	81	....
Picacho to Yuma	50	....
Picacho to Castle Dome Landing	13	....
Pot Holes to Yuma	14	....
Needles	....	291



COLORADO RIVER AT HEAD OF GREAT VALLEY.

SILT.

The river water is always muddy, the percentage of silt being much greater during the high spring and early summer stages of the stream.

Mr. R. H. Forbes, of the experiment station of the Agricultural Department at Tucson, Ariz., took daily samples of the water in the river at Yuma from January 10, 1900, to January 19, 1901, and has made complete chemical examinations of the samples both as to silt and as to soluble salts. The following is a summary of the results for silt:

Silt carried by Colorado River at Yuma, Ariz., from January 10, 1900, to January 19, 1901.

	Jan. 10 to Apr. 7, 1900.	Apr. 7 to July 12, 1900.	July 12 to Sept. 26, 1900.	Sept. 26, 1900, to Jan. 19, 1901.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Silt, by volume, wet	0.184	0.526	0.45	1.781
Silt, by weight, dry	.0719	.2937	.1744	.4807

The water is not especially good for either domestic or irrigation purposes, but it can not be said to be bad water, and it is of a higher grade than the waters of Gila or Salt rivers. The handling of the silt in the canals is probably the most serious problem in connection with irrigation from this stream. It is believed, however, that if the water is conducted in the canals at as high or higher velocities than it has in the river at the points of diversion this difficulty might be avoided.

This subject should be studied very carefully. It is possible that if a diversion dam 20 or 30 feet in height should be built it would, owing to the slight grades of the stream, afford a sufficient settling basin to permit the deposit of the heavier material suspended in the water. The canal diverting water near the dam would then draw on a supply largely clarified. A series of sluice gates should be arranged in the dam, which, by being opened, would permit scouring out the accumulated silt for several hundred feet back from the dam and maintain this flush basin for an area near the intake of the canal. This water, being reduced to a relatively low velocity at the weir, could then be diverted into the canals at higher velocities and with less danger of deposit in the distribution system. It is not desirable to remove all the silt, for it should be an aid in the agricultural development of the country, as it would, if conveyed to the land by irrigation, tend to restore and fertilize it.

ANALYSES OF WATER.

The following analyses of the water of Colorado River were made by the Bureau of Soils of the Department of Agriculture:

Analyses of water of Colorado River.

Ions.	Location.			
	Head gate Imperial Land Co.		Calexico.	
	Per cent of total solids.	Parts per 100,000.	Per cent of total solids.	Parts per 100,000.
Ca	9.81	9.00	11.48	10.00
Mg	3.59	3.51	2.98	2.60
Na	16.35	14.99	11.14	9.70
K	0.65	0.60	6.20	5.40
SO_4	25.96	23.70	39.03	33.99
Cl	22.25	20.40	13.90	12.11
HCO_3	21.38	19.50	15.27	13.30
Total	99.99	91.70	100.00	87.10

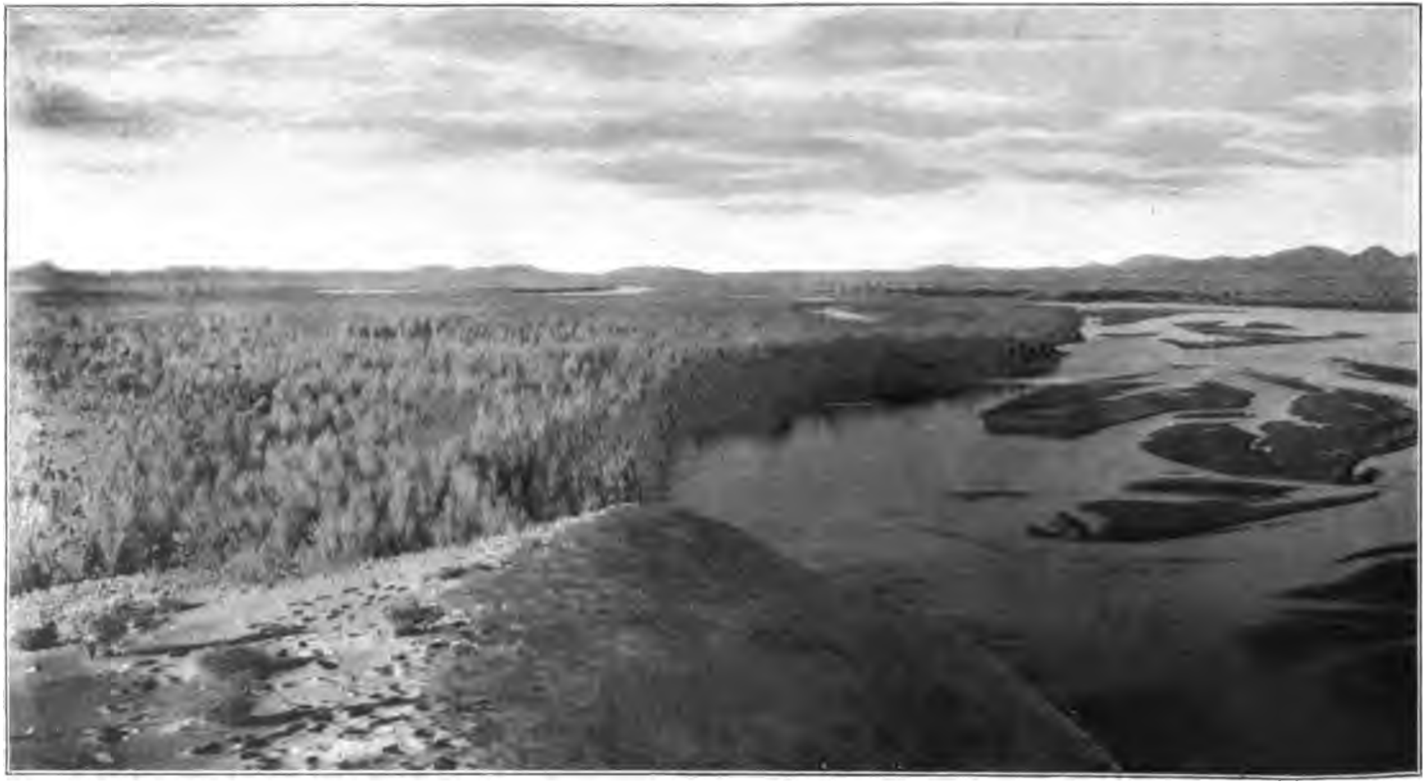
WATER SUPPLY.

Colorado River, draining 225,000 square miles and receiving its principal water supply from the melting snows of Colorado and the high mountains of Utah and Wyoming, attains its maximum annual flood stage, 50,000 second-feet, during the month of June. The river gradually decreases in volume through late summer and fall, reaching its lowest stage, 4,000 second-feet, in midwinter, the cold-weather period of the high mountains. The following measurements of the flow of the river have been made at Yuma:

Discharge measurements of Colorado River at Yuma, Ariz.

	Second-feet.		Second-feet.
January 17, 1895	9,737	July 9, 1902	14,799
April 18, 1895	21,094	October 11, 1902	6,030
July 10, 1895	45,533	October 14, 1902	4,798
May 20, 1896	57,903	October 17, 1902	3,559
January 9, 1902	3,637	October 21, 1902	4,203
February 20, 1902	3,239	October 24, 1902	3,547
May 30, 1902	38,400		

This water supply is particularly adapted to the demands of irrigation, as the period of greatest supply is coincident with that of greatest demand, and, conversely, the low stages of the river are during the season when plant life is least vigorous and the demands of irrigation are not great. The river can probably furnish an abundant supply of water to irrigate 500,000 acres of land without storage.



VALLEY OF COLORADO RIVER.

SUMMARY.

In conclusion it may be stated: (1) That fully 400,000 acres of river-bottom lands between Camp Mohave and Yuma are easily irrigable from the Colorado River; (2) that extensive interior diversions could possibly be made for the reclamation of larger areas of arid lands near Yuma; (3) that reservoir sites exist at Needles, above Williams River, and above the Picacho dam site; (4) that owing to the low grade of the stream and the high percentage of silt carried by the water, diversion weirs probably will be necessary to raise the water level at the head of the canal and to act as settling basins therefor; (5) that the mining resources of the bordering mountain ranges are of such character as to justify the belief that general population and development of the country will result in extending the mining industry in this great interior valley; (6) that the problem of the most extensive and economic use of this river is entirely too vast to be grasped either by a reconnaissance survey or by numerous independent line surveys, and that the only practicable way of solving the problem is by the aid of a series of topographic maps extending from the Mexican border to Camp Mohave.

HISTORICAL REVIEW OF EXPLORATIONS ALONG THE LOWER COLORADO RIVER.

In connection with the discussion of the possibility of utilizing Colorado River, it is interesting to note the earlier history of the stream, and important to consider it from the standpoint of navigation. The construction of dams and diversion canals will bring about some modification in the stream, which may or may not be favorable to the interests of navigation. These interests are so small that it may be questionable whether they are worth considering. Under this heading are inserted some notes bearing upon the subject. Facts concerning the early history of the river have been brought together by Mr. Jeremiah Ahern, and data concerning navigation and related facts have been added by Mr. Lippincott.

In 1539 Ulloa sailed to the head of the Gulf of California, and, noting the turbid condition of the water, inferred that a great river entered the gulf near its head. He, however, did not see the river, but indicated its supposed position on a sketch map made by him at the time. The actual discovery of Colorado River took place in 1540, three explorers, one by sea and two by land, having reached it in that year. Alarcon, the first to arrive, sailed up the Gulf of California to its head, entered Colorado River and ascended it in boats for fifteen days. He gives the distance as 85 Spanish leagues—an equivalent of 234 miles—which would bring him to near the present site of Ehrenberg, Ariz.

Diaz, separating from Coronado's main party near the present site of Ures, Mexico, made a journey to the mouth of the Colorado, and, proceeding up the river to a point several leagues above the Gila, crossed and explored some of the country to the west.

Cardenas, another lieutenant of Coronado's, traveling through what is now northern Arizona, according to the chronicler of the expedition, "arrived at a river the banks of which seemed to be more than 3 or 4 leagues apart in an air line." This is the first written description of the Grand Canyon of the Colorado.

Oñate, during his expedition in 1604–5 from the Rio Grande to the mouth of the Colorado, came to a stream flowing northwesterly, which he named Colorado—the Little Colorado of the present day. So far as known, he was the first person to use the name Colorado. Then, traveling in a southwesterly direction to Williams River, he followed it to its junction with the Colorado, and, following the latter stream to the gulf, returned by the same route. He also noted the Gila.

In 1744 Father Sedelmayer followed the Gila to the great bend, and from there went overland about 40 leagues to the Colorado, reaching it near Williams River.

In 1771 Father Garcés journeyed down the Gila to its junction with the Colorado, thence down the latter stream at least as far as tide water. In 1774 he was a member of Captain Anza's expedition which traversed the Gila to its mouth, crossing the Colorado at this point and proceeding across the desert to San Gabriel and Monterey. Anza gives the width of the Colorado at the place of crossing as 550 feet and its depth somewhat more than 5½ feet. He was informed by the Indians that a branch of the Colorado ran westward and northwestward. This may be a reference to an overflow from the Colorado to Salton Sea.

During the eighteenth century the Lower Colorado was visited by several other Catholic priests. Father Kino, who made the first map of that region in 1701, spent from 1690 to 1702 in traversing the region along the Gila and Colorado.

In 1775–76 Father Garcés explored the Colorado from the mouth of the Gila to the present site of Camp Mohave, and his journal gives extensive information in regard to the geography of the country passed through. In 1780 he established the mission Purisima Concepcion opposite the mouth of the Gila, and on the site where seventy years afterwards Fort Yuma was established. In the same year he also founded the mission of San Pedro y San Pablo on the right bank of the river a few miles below the mouth of the Gila. Both of these missions were destroyed by Indians in 1781 and about 50 Spaniards were killed, including Father Garcés and 3 other priests. This was the only attempt to establish missions on the Colorado.

In 1776 another Catholic missionary, Father Escalante, traveled from Santa Fe to Utah, and, after having discovered Utah Lake, pursued a southwesterly course toward the sources of the Virgen, and crossed to the Colorado, which he forded just above the point where it enters Arizona.

In 1777 Father Font, who had been a member of Anza's expedition of 1775–76, traveling eastward from Monterey, Cal., crossed the Colorado near the present site of Camp Mohave.

The foregoing include all of the more important exploratory expeditions to the Lower Colorado up to the beginning of the nineteenth century.

As early as 1825 American trappers appeared along the Colorado River. On his second overland journey to California in 1826 Jedediah S. Smith followed the Colorado from the mouth of the Virgen to near the present crossing of the Santa Fe Railroad. He was the first American to reach California by the overland route. In 1825 James O. Pattie made two trips down the Gila, and in the following year went down the Gila to its junction with the Colorado and up the Colorado and across the Rocky Mountains. Steamboating on the Colorado began in 1851.

From 1846 to the beginning of the civil war the Lower Colorado was visited and explored by surveying and exploring parties under the direction of the War Department. The most detailed examination of the river made during this period was by Lieut. J. C. Ives in 1857–58. He ascended the river in an iron steamboat 50 feet long, built in Philadelphia and shipped in sections to the mouth of the Colorado via San Francisco. A very detailed examination, with the view of determining how far it was navigable for steamboats, was made from the mouth of the Colorado to near the mouth of the Las Vegas Wash.

After the close of the civil war topographic parties, under the direction of the Chief of Engineers, U. S. Army, made various preliminary surveys in the region along the Lower Colorado. Lieut. E. Bergland, who examined the Lower Colorado in 1876, states that during stages of high water the river changes its channel to a considerable extent, also that portions of the bottom lands are subject to overflow, and that consequently it would be necessary to build levees to prevent the river from overflowing the bottom lands adjacent and destroying the irrigation canals and ditches.

IMPROVEMENT OF THE RIVER.

The matter of improving the river for navigation has been considered by the army engineers and information has been published in the annual report. The following extracts are taken from the Annual Report of the Chief of Engineers, U. S. Army, for 1886, part 3, pages 1931 and 1932:

> January 13 the barge dropped down 46 miles to Bulls Head Canyon, when it was decided to take advantage of the low stage for work on an isolated rock directly in

the channel and in very swift water. The area of this rock at low water was 30 feet by 15 feet, and its highest point 4 feet above that level.

This rock was drilled and blasted down to 1 foot 5 inches below low water, which makes it no longer an obstacle in the present condition of the river.

Near the lower end of the canyon a point of rocks projected from the west bank, confining the river at 4-foot stage to a width of 120 feet, throwing a strong current against the nearly vertical rocks of the west bank and making the passage by steamers very dangerous. This point was graded off to 5 feet above low water, which it is thought will make the passage safe.

The following statistics, showing the entire business on the Colorado River for the year ending June 30, 1886, are furnished by the Southern Pacific Company:

Number of passengers transported	130
Freight transported . . . tons	4,695

The following extracts are from the Annual Report of the Chief of Engineers, U. S. Army, for 1879.

The following is from the report of Lieut. Col. C. Seaforth Stewart:[a]

As to the improvements below Camp Mojave and above Ehrenberg, there is so little prospect now of anything but greatly diminished traffic in the river since the practical completion of the railway eastward from Yuma to Maricopa Wells, that I do not feel justified in recommending any expenditure under the plan submitted for them, nor indeed for those higher up.

The following is from the report of Lieut. A. H. Payson:[b]

The following are the distances from the mouth of the river to various points along it. The information on which they are based is imperfect and conflicting, and they can only be regarded as probably approximations.

From the Gulf to Yuma is by river 150 miles, though in a straight line only 75 miles.

Distance from Yuma to—	Miles.
Castle Dome Landing	28
Ehrenberg	111
Camp Colorado (Indian agency)	179
Aubrey (Bill Williams Fork)	200
Camp Mojave	285
Hardyville	297
El Dorado Mill	344

Although it is difficult to make the distinction exact, of the 297 miles between Yuma and Hardyville about 100 miles may be considered canyon, the rest as having the valley characteristics before described.

They succeed each other as follows:

	Miles.
Valley from Yuma to Picache Canyon	13
Picache Canyon	46
Great Colorado Valley	120
Aubrey Canyon	37
Chimehuevas Valley	18
Mojave Canyon	17
Mojave Valley	46

From Camp Mojave to El Dorado is canyon with the exception of the little valley of Cottonwood Island, 5 miles long and from one-fourth to one-half a mile in width.

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[a] Ann. Rept. Chief of Engineers, U. S. Army, for 1879, Pt. II, p. 1771.

[b] Ibid., pp. 1776–1782.

Levels and discharge.—By the railway surveys the height of low-water surface at Yuma is 117 feet above the sea. The distance being by river 150 miles, we find for the corresponding low-water slope 0.78 feet per mile. It was determined at Yuma by actual leveling in March, 1876, by party under Lieutenant Bergland as 1.2 feet per mile.

A second railway survey crosses the river 6 miles above the "Needles," in Mojave Canyon, and 245 miles above Yuma. By leveling from a bench mark of this survey we found the surface of the water January 6, 1879, to be at reference 425.4, which gives the average slope from this point to Yuma as 1.26 feet per mile.

This seems very probable, the fall per mile at Camp Mojave having been also determined by the levels of Lieutenant Bergland's party as 1.2 feet.

From the railway crossing to Camp Mojave is 40 miles. Calling the slope 1.3 feet per mile, low-water surface at Camp Mojave would be 52 feet above that at the Needles, or reference 477 above sea.

By careful and long-continued barometric observations in 1876 Lieutenant Bergland found the surface of the river, then nearly at its lowest stage, at Camp Mojave, to be at reference 588. This is a grave discrepancy for which it is difficult to account. It seems hardly possible that the railway survey could be so much in error. While taking the barometric determination as correct, we get the average low-water slope between Yuma and Camp Mojave 2.06 feet per mile, which is nearly double what it was found to be by actual levels at both these places and larger than the average slope determined by my own levels from Camp Mojave north, for more than 50 miles, though this latter stretch of river, flowing as it does in a canyon and over frequent rapids, has visibly a greater fall than that below.

It is to be noted also that Camp Mojave, being one of the stations used by Colonel Williamson, its altitude is given in his work on the barometer and is about 100 feet less than that found for it by Lieutenant Bergland's party. The post being on a level mesa there could not have been any considerable difference in the position of the instruments in the two cases.

The level line of my party began at the foot of Pest House Rapids, a few miles above Camp Mojave, and continued to El Dorado Canyon, the distance being 50.5 miles and the mean slope 2.03 feet per mile.

Two carefully run lines, each about 3 miles in length—one in the valley of Cottonwood Island, the other over some of the swiftest rapids—gave 1.4 and 3.7 feet per mile, respectively, for minimum and maximum fall in this portion of the river.

It will thus be seen that the fall is very unequally distributed, the profile showing a series of slack-water pools, separated by rapids.

This point can be further illustrated as follows:

The fall from El Dorado Canyon to foot of Cottonwood Island Valley is 56.08 feet, the distance being 27 miles. Separate levelings were made at the principal rapids found in this portion, and it was shown that nearly half of the total fall occurred in less than one-twentieth of the distance.

At the swiftest place the river fell 5.155 feet in 2,100, corresponding to 12.67 feet in a mile, notwithstanding the fact that the water's surface was only taken at the extreme limits of the special survey made here, and that the distance includes, consequently, not only the rapid proper, where most of the fall probably took place, but also considerable reaches of slacker water above and below it.

Taking the railway reference of low water at the "Needles," the following is the approximate height of low water at El Dorado Canyon, the northern limit of my examination:

	Feet.
Rise from sea to Yuma	117
Rise from Yuma to "Needles"	308
Rise from "Needles" to Pest House Rapid	65
Rise from Pest House Rapid to El Dorado	103
Total	593

Commerce and navigation.—Before the railway reached the Colorado River at Yuma, all supplies sent from San Francisco to the interior of Arizona went by sea-going steamers to the head of the Gulf of California, and were there transferred to the river boats of the Colorado Steam Navigation Company, to be left at various points along the river and freighted overland to their destination. The most considerable portion of the transportation was between the gulf and Yuma, which was the starting point for Tucson; and of that on the upper river the greater part was to and from Ehrenberg, from whence there was the most convenient road to Prescott and the important country adjacent.

Above Ehrenberg we find only the Indian agency at Camp Colorado, the so-called towns of Aubrey and Hardyville, the military post of Camp Mojave, and the little mining camp at El Dorado Canyon.

Aubrey and Hardyville, are each small adobe buildings, occupied as stores, at which supplies are landed for a few mining camps in the interior, of which the most important are Signal, Hackberry, and Mineral Park.

The mine at El Dorado is said to be a good one, but the company is supposed to be in financial difficulty, and its abandonment in the near future is, to say the least, not impossible.

As soon as the railway crossed at Yuma, the best part of the river business was stopped at once; the steamers passed into the hands of the railway company; the old establishment at the mouth of the river was abandoned and all trips from thence to Yuma discontinued.

During the past winter the Southern Pacific road has been rapidly pushed into Arizona, and, when operations are discontinued for the hot weather of the coming summer, its terminus is expected to be at Maricopa Wells, 190 miles east from Yuma. When this happens, freight for Prescott and its tributary districts will no longer go by boat to Ehrenberg, but by rail to Maricopa Wells; and with this change disappears at once not only the greater portion of the remaining need for river transportation, but also the chief reason for the existence of the town of Ehrenberg itself.

We are therefore confronted with the fact that our estimate of the necessity for increased communication facilities by the river must be based on the needs of the country above Ehrenberg dependent on it for supply.

It is of course not improbable that new mines may be discovered in the very imperfectly known country adjoining the Colorado's course, but such a consideration is altogether too uncertain a one to be entertained at present; while with reference to future agricultural development in the very limited areas of fertile land through which the river flows it may simply be said that none will be possible unless preceded by such works of reclamation and control as would in themselves definitely settle the question of navigation.

Roughly stating the extent of these arable lands as 500 square miles, by the ordinary methods of estimating the quantity of water needed for their irrigation, it will be seen that more than one-half of the low-water discharge would have to be diverted for that purpose.

By the railway company I have been furnished with statistics of the river traffic since it came under their management. They cover a period of nineteen months, from May 21, 1877, to January 1, 1879.

Before the first-named time there are no data which can be obtained.

I have tried to separate these statistics for the different sections in the following table:

Freight carried.

	Tons of 2,000 pounds.
1. Between Yuma and Ehrenberg	7,973.3
2. Between Yuma and Ehrenberg and points between Ehrenberg and Hardyville	4,784.7
3. Between Yuma and points above Hardyville	77.9
4. Points between Ehrenberg and Camp Mojave and points above Camp Mojave	25.1
5. Between Camp Mojave and points above	2,864.2
Total freight business for nineteen months	15,725.2

Probably the greater part of the item in the fourth line of the table was for Hardyville. The fifth line contains a large item which I believe consists mainly, if not wholly, of firewood, towed up from Cottonwood Island—26 miles—for the supply of the quartz mill at El Dorado Canyon.

I have not been able to get statistics of the passenger traffic in a very intelligible form, but the following numbers will give some idea of its amount:

Passengers carried.

From Yuma	1,621
From Ehrenberg	687
From Aubrey	230
From Castle Dome	71
From Chimney Peak	64
From Picache Mill	3
From Roads Ranch	4
From Camp California	6
From Gastons	2
From Taylors	2
From Drift Desert	9
From Swan Lagoon	6
From Quien Sabe	1
From Indian Agency	21
From Empire Flat	8
From Chin-e-hue-vis	3
From Camp Mojave	100
From Hardyville	35
From Cottonwood Island	2
From El Dorado	11
Total	2,286

It remains to show what facilities for commerce the river affords in its present unimproved conditions.

The head of high-water navigation was put by Lieutenant Ives in the lower part of the Black Canyon, and a steamer has actually ascended to the now abandoned town of Colville, 25 miles above the mill at El Dorado, but the difficulties and dangers of this upper portion of the river, combined with the lack of any present reason for going there, have made the latter place the practical upper limit of the navigable portion of the stream.

To this point the boats in use on the Colorado can go at any time from the spring rise till the latter part of August or fore part of September without other obstacles than those interposed by the swiftness of the current.

After that Hardyville becomes the low-water head of navigation, and can generally be reached, with more or less difficulty, at all times, though occasionally, in extremely low stages, freight for this place has to be landed at the foot of Pest House Rapid, 4 miles below.

It may be safely said, therefore, that if there is freight enough to pay for the trouble it can be sent to the foot of Pest House Rapid in all seasons and to El Dorado Canyon for from three to four months in each year.

The chief obstacles to the low-water navigation are encountered in the valleys, which may be said to form an almost continuous obstruction, over 200 miles in length, while in the canyons there are comparatively few.

Above Camp Mojave there is probably quite as much water as below, but the general character of the bars changes from yielding and semifluid sand to cobble of constantly increasing size, and steamers are unable to force their way over or through them, as they are continually obliged to do in the river below.

The boats in use on the Colorado are from 150 to 170 feet long, 30 to 37 feet beam, and draw slightly more than 2 feet.

Their load is carried on board in high stages, but during low water it is placed on a barge and the latter towed astern by a long line, which reaches to a tow post set amidship in the steamer's hull.

Previous knowledge of the channel is of no avail, and the pilot judges the course of the river at each moment by the appearance of the water surface, shape of the bars, direction of the drift, and other slight indications significant alone to his experienced eyes. A sounding pole is kept going constantly, and the boat is frequently aground each day. She is then hauled over by all sorts of devices, with spars, anchors, and capstan, or, as a last resort, is backed up to the bar and digs her way slowly through by stirring up with the wheel the loose material of the bottom, until enough has been carried away by the rapid current. In this manner they have actually made a cut for themselves and hauled a barge through a bar of fine gravel, over which there had been found only from 2 to 3 inches of water.

A trip from Yuma to Hardyville can generally be made in low stages in from ten to fourteen days; the return in from five to ten.

Much uncertainty is introduced into these calculations by the wind, which occasionally blows with extreme violence straight up or down river, greatly hindering or even completely preventing navigation for three or four days at a time.

As a result of all this and the lack of any competition, transportation is extremely expensive, freight being charged for in pounds and the weight estimated by measurement. Cost will vary greatly for different classes of supplies, but the average price for the Government from Yuma to Camp Mojave is said to be 4 cents per pound.

* * * * * * *

Summary.—The Colorado River between Yuma and Camp Mojave, about 300 miles, is generally navigable, though with more or less difficulty, at all seasons of the year. It has been shown that most of the Ehrenberg trade will disappear during the coming summer. Leaving it out, therefore, the freight carried to and from all points on this portion of the river has, during the past two years, averaged less than 300 tons per month.

The principal obstructions to navigation being the shoal and shifting channels in the valleys, no plan will give any permanent change for the better unless it provides for the entire and certain confinement and control of more than 200 miles of river, while there is manifestly no present justification for so vast an expenditure as the execution of such a plan would entail.

Improvements, however, could be effected, and would probably be permanent, at certain gravel bars for about $13,000.

The section of the river between Camp Mojave and El Dorado Canyon can at present be navigated for more than three months in the year, and throughout it low-water navigation could probably be provided for about $90,000, though unforeseen contingencies might increase that amount.

Most of the freight which seeks to go above Camp Mojave is for Hardyville, while the distance between the two places is only 7 miles and traversed by a good road.

During the entire nineteen months preceding January 1, 1879, less than 100 tons was transported from below to points above Hardyville, the principal and only important reason for the navigation of the upper portion of the river being the supply of wood to the El Dorado mill.

There seems no reason why this business could not perfectly well be done during high water in the future as heretofore, and I am therefore decidedly of the opinion that the interests now involved are very far from warranting the expenditure of so much money, not really to enable the transportation company to accommodate them, but merely to render it more convenient to do so.

In a country whose only possible future lies in the discovery of mineral wealth such discovery should precede and create the demand for increased communication facilities, its case being widely different from that of an agricultural district, where the construction of proper means of communication may in itself make practicable and hasten the development of its resources.

COLORADO.

This State, although not the largest in size, leads in the area of land irrigable. The average value of the crops raised is not so great as in California, as the altitude is higher and the climate colder. In any comparison, however, it must be remembered that California lies to a considerable extent in humid or semihumid regions, while Colorado is entirely arid, except, possibly, in case of the higher mountain valleys. Through the necessities of the case, therefore, reclamation has been carried on more widely than in California, but as regards details not so completely as in the somewhat tropical valleys near the Pacific coast.

The State of Colorado as a whole may be considered as consisting of two parts—one draining toward the east into the Atlantic Ocean or Gulf of Mexico, the other toward the west into the Gulf of California and Pacific Ocean. On the eastern side, sloping toward the Plains, the reclamation of arid land has progressed to such a degree that all of the ordinary flow of the stream is now utilized, and even the flood discharges are to a large extent controlled by reservoirs built by private or corporate capital. Further reclamation depends upon the more complete construction of similar or larger works and the distribution of the stored waters among the present owners of the reservoirs and users of the natural flow of the streams. The problems are thus exceedingly complicated, and for successful solution necessitate long-continued measurements and a careful study of the existing situation.

On the western slope of the State the conditions are almost reversed. There the water supply has not been used to its full extent and there is relatively a small amount of land to be irrigated. The rivers are large and have cut their way deep into the valleys, having only narrow and not continuous flood or valley lands, these being usually first on one side and then on the other of the river.

An exaggerated idea of the size of these streams is prevalent, due to the facts that they are large for the arid region and that the use of them has been small. They are by no means unlimited in capacity, as frequently stated; on the contrary, it is probable that the full development of the available land will necessitate taking out the entire ordinary summer flow and possibly supplementing this by means of storage.

The area irrigated in Colorado, as shown by the recent census, aggregates 1,611,271 acres, this being an increase of about 81 per cent in ten years. The amount irrigated in 1889 was 890,735 acres. The number of irrigators has increased at approximately the same ratio and now amounts to 17,613. This irrigated land is scattered in nearly every county, the largest bodies being in the north, in the vicinity of Greeley, also along Arkansas River east of Pueblo and in Rio Grande Valley.

Of the entire land surface of the State, a little over 3 per cent is included in what may be termed "improved land," and about two-thirds of this has been irrigated. It is probable that this area can be greatly increased, especially in the western part of the State, but progress will be relatively slow, as the works needed will be expensive. The area of vacant public land on June 30, 1901, is shown by the table below. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Area of unappropriated, reserved, and appropriated lands in Colorado on June 30, 1901.

County.	Area unappropriated and unreserved	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Arapahoe	843, 139	....	2, 179, 581	3, 022, 720
Archuleta	521, 816	124, 800	127, 144	773, 760
Baca	1, 155, 888	1, 000	462, 952	1, 619, 840
Bent	468, 228	4, 960	484, 892	958, 080
Boulder	241, 912	....	238, 728	480, 640
Chaffee	644, 504	1, 600	137, 256	783, 360
Cheyenne	494, 475	511, 880	137, 325	1, 143, 680
Clear Creek	206, 913	....	65, 087	272, 000
Conejos	615 068	....	285, 412	900, 480
Costilla	378, 924	612, 000	126, 516	1, 117, 440
Custer	155, 128	56, 000	234, 312	445, 440
Delta	482, 525	179, 160	106, 955	768, 640
Dolores	607, 910	....	32, 090	640, 000
Douglas	25, 910	163, 500	379, 550	568, 960

Area of unappropriated, reserved, and appropriated lands in Colorado on June 30, 1901—Continued.

County.	Area unappropriated and unreserved	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Eagle	809,505	106,168	99,367	1,015,040
Elbert	353,977	....	831,303	1,185,280
El Paso	245,397	129,908	990,455	1,365,760
Fremont	664,272	....	281,648	945,920
Garfield	1,182,998	570,240	198,122	1,951,360
Gilpin	66,175	....	17,025	83,200
Grand	767,121	227,000	204,599	1,198,720
Gunnison	1,657,854	69,120	370,306	2,097,280
Hinsdale	614,204	....	27,716	641,920
Huerfano	427,933	134,400	421,347	983,680
Jefferson	202,403	23,900	322,817	549,120
Kiowa	651,108	2,040	486,052	1,139,200
Kit Carson	695,972	556,959	134,589	1,387,520
Lake	177,473	1,820	72,227	251,520
La Plata	904,541	7,000	271,179	1,182,720
Larimer	1,902,524	....	873,156	2,775,680
Las Animas	1,732,002	168,880	1,172,398	3,073,280
Lincoln	938,799	....	695,121	1,633,920
Logan	266,984	....	842,136	1,109,120
Mesa	1,652,437	269,340	195,983	2,117,760
Mineral	516,068	....	47,132	563,200
Montezuma	797,954	392,000	162,366	1,352,320
Montrose	1,241,025	....	224,575	1,465,600
Morgan	547,206	....	261,754	808,960
Otero	807,643	....	499,237	1,306,880
Ouray	319,985	....	36,495	356,480
Park	518,335	452,000	363,425	1,333,760
Phillips	3,633	....	429,647	433,280
Pitkin	497,162	51,914	80,044	629,120
Prowers	496,446	....	528,834	1,025,280
Pueblo	557,842	64,000	944,238	1,566,080
Rio Blanco	1,532,060	460,800	86,500	2,079,360
Rio Grande	502,961	....	348,879	851,840
Routt	3,832,033	204,200	430,967	4,467,200
Saguache	1,416,933	97,000	258,227	1,772,160
San Juan	256,780	....	23,540	280,320
San Miguel	769,142	....	69,258	838,400
Sedgwick	40,482	....	301,918	342,400
Summit	228,237	....	157,683	385,920
Teller	59,732	50,572	242,336	352,640

Area of unappropriated, reserved, and appropriated lands in Colorado on June 30, 1901—Continued.

County.	Area unappropriated and unreserved	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Washington	142,050	....	545,310	687,360
Weld	975,300	....	1,532,220	2,507,520
Yuma	235,433	....	508,247	743,680
Total	39,050,461	5,694,161	21,588,178	66,332,800

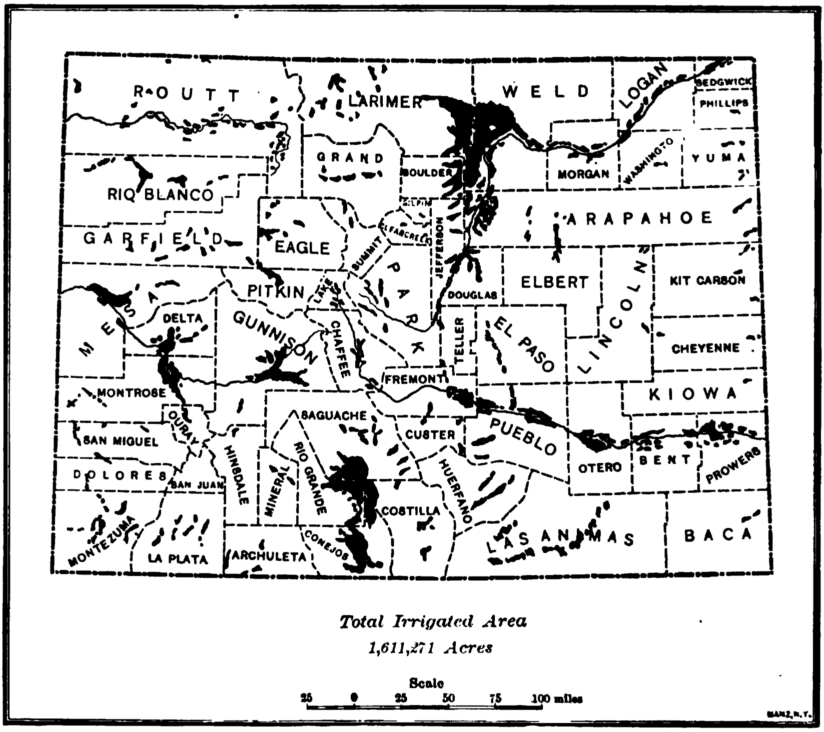

FIG. 15.—Map of irrigated areas in Colorado.

GUNNISON RIVER DIVERSION.

One of the first projects taken up for consideration in the reclamation work is that known as the Gunnison River diversion. This stream is a tributary of Grand River, emptying into the latter near the point where the city of Grand Junction is located. Attention was originally called to this locality by petitions from the citizens of Colorado and representations made as to the feasibility and importance of the work. Measurements of flow of water in this vicinity have been carried on for several years, and in the summer of 1901 a preliminary examination was made to ascertain the geologic structure of the area through which a tunnel might be built, the difficulties to be encountered, and the probable cost of the work. Upon the passage of the reclamation act, work was continued on the preparation of definite plans.

LOCATION OF THE PROJECT.[a]

The lands to be reclaimed are in Uncompahgre Valley, in the southwest quarter of the State. The valley comprises parts of Ouray, Montrose, and Delta counties, and is watered by Uncompahgre River and its tributaries. Uncompahgre River rises in the San Miguel Mountains, in the southern part of Ouray County. Some of the mountains about its headwaters rise to more than 14,000 feet, but the greater part of the drainage basin lies at altitudes varying from 7,000 to 10,000 feet, the entire range of elevation being from 11,000 feet down to 5,100 feet in a distance of 78.5 miles.

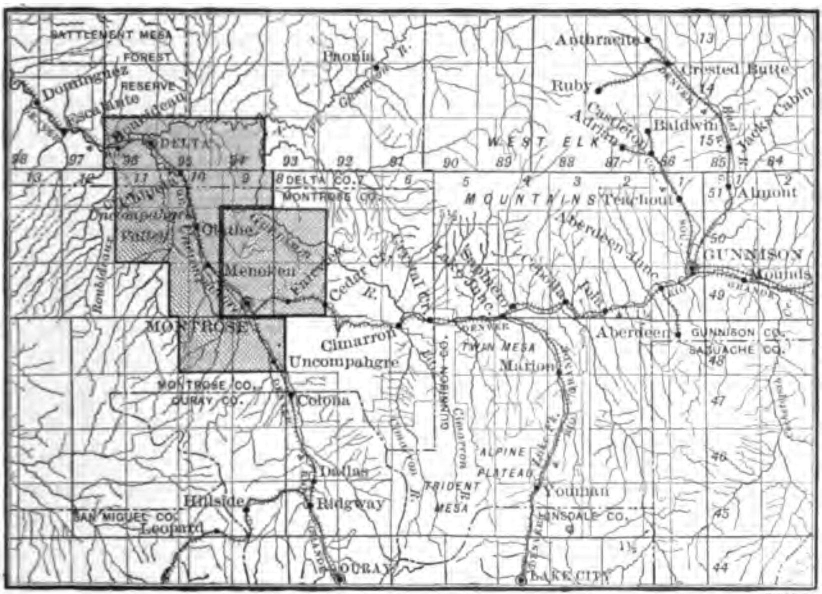

FIG. 16.—Map of lands temporarily withdrawn near Gunnison River, Colorado. (Portion of lands reserved has been restored since map was drawn.)

The river and its tributaries cover two Colorado water districts—No. 68, or all of that portion of the drainage basin which is in Ouray County, and No. 41, or that portion which is in Montrose and Delta counties. The earliest irrigation practiced in this valley was about 1875, the first crops raised being principally hay, for shipment to mines; but later, when it was demonstrated that the plains of the valleys when irrigated were capable of raising great crops, and especially when it became known that fruit would be one of the staple products of the region, there was a great rush for land, and a number of large irrigation enterprises were begun. This stage of irrigation development commenced about 1884.

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[a] From report of A. L. Fellows.

When the valley was first settled it was generally believed that Uncompahgre River and its tributaries would carry enough water for the irrigation of all the tillable lands, amounting to approximately 175,000 acres, and on this account a very large portion of this land was filed upon. It was not long, however, before it was discovered that there was an insufficient supply of water in the stream to irrigate all of the lands entered. In consequence great tracts were abandoned, and the houses, many of them of considerable value, were deserted. At the present time there are about 30,000 acres of land irrigated, a great diversity of crops being raised, and would-be settlers, who are constantly on the lookout for means of procuring water for irrigable lands, have endeavored in every possible way to store water by means of reservoirs and to find every source from which water could be obtained for the purpose of irrigating the now dry region.

Ditches and canals on Uncompahgre River from Fort Crawford to its mouth.

	Name.	Capacity.	Length.		Name.	Capacity.	Length.
		Sec.-feet.	*Miles.*			*Sec.-feet.*	*Miles.*
1	Reservation	30	6	18	Frost, east	6	2
2	Montrose and Delta	300	34	19	Ironstone	120	15
3	Logan	25	5	20	Satisfaction	10	1
4	Midland, east	20	6	21	Home Run	30	8
5	Chipeta	25	5	22	Colorado, east	20	6
6	Loutzenheiser, east	150	35	23	Delta Chief	30	6
7	Montrose City, east	10	2	24	Home Stake	15	2
8	Valverde	15	2	25	Foster	10	1
9	West Montrose	10	1	26	Danlavay, east	8	1
10	North Mesa, east	20	4	27	Rustler, east	50	10
11	Rice, east	10	2	28	Swanson, east	15	2
12	Steitler, east	10	2	29	Garnett, east	10	10
13	Sunrise	20	2	30	Chipeta, east	30	3
14	Selig, east	25	8	31	Bowles Many, east	8	2
15	Eagle, east	35	4	32	Eggleston, east	15	2
16	Spring Creek	20	6	33	Delta City	20	2
17	Hall, private	5	3				

Within 20 miles of Uncompahgre Valley, in a nearly easterly direction from it, and flowing nearly parallel with Uncompahgre River for a considerable distance, is Gunnison River, flowing through the Grand Canyon of the Gunnison, as it was named by Hayden. The characteristics of Gunnison River are in many respects very different from those of the Uncompahgre, although the two streams are near each other and although the Uncompahgre flows into the Gunnison at Delta. Gunnison River is a stream of considerable size, as will be seen from the tables of discharge on pages 143 to 145; but there is little land along its valley that can be irrigated, and, furthermore, the most of this land is so elevated that it is of small value when compared with the fruit-raising lands of Uncompahgre Valley. The water districts along this stream are Nos. 28, 59, 62, 40, and 42, but, as shown by the reports of the water superintendent of the irrigation division in which these districts lie, little land is or can be irrigated directly from the waters of the Gunnison.

The possible diversion of the waters of Gunnison River into Uncompahgre Valley for the irrigation of its lands has been discussed for many years. Private or local capital has been unable to handle the enterprise, owing to the magnitude of the work. Preliminary investigations made by engineers and others locally interested had demonstrated that it was possible to divert the waters of the Gunnison and to reach a point upon the Uncompahgre side sufficiently high to irrigate the great bulk of tillable lands in that valley. Beyond this point investigation had not gone, the cost of a complete survey being too great for local subscriptions. Special examinations had been made, however, particularly by Mr. John A. Curtis, county surveyor of Delta County, and by Mr. W. H. Fleming, a surveyor of Montrose, Mr. Curtis examining more particularly the divide between the two valleys and Mr. Fleming running level lines across the ridge at chosen points.

In the summer of 1901 Mr. A. L. Fellows, irrigation engineer and resident hydrographer of the Geological Survey, was instructed to begin systematic surveys, cooperating with Mr. C. H. Fitch, topographer and consulting engineer. The plan determined upon was that a survey should be made, showing by means of contours the region dividing Gunnison and Uncompahgre valleys, so that a selection of the shortest and most feasible line might be made from the map.

PROBLEMS PRESENTED.

As previously stated, Gunnison and Uncompahgre rivers flow in approximately parallel courses for a considerable distance—about 35 miles—the Uncompahgre following a comparatively straight course from its source to its junction with the Gunnison at Delta, while the Gunnison flows in a nearly westerly direction for a distance of about 100 miles from its head. At the mouth of Cimarron River the main stream turns and for about 20 miles flows northwesterly, through a canyon cut in a complex of granite, gneiss, and various schists, then turns north, in which direction it flows for 15 miles (still keeping in the granite) to its junction with the North Fork of the Gunnison, where the stream again turns and flows directly westward to its junction with the Uncompahgre, near Delta. The Denver and Rio Grande Railroad follows the course of the Gunnison for a long distance, but at the mouth of Cimarron River the canyon of the Gunnison becomes so rugged that the railroad leaves the stream and ascends a divide, known as Cerro Hill, between the two valleys, then descends on the Uncompahgre side to the town of Montrose, follows Uncompahgre River to its junction with the Gunnison at Delta, and then follows the latter stream to its mouth. The Vernal Mesa is that portion of the region which divides the two valleys, commencing at the mouth of the Cimarron and extending northwesterly between the Denver and Rio Grande Railroad track on the south and the Gunnison Canyon on the northwest to about the point where the Gunnison makes its turn to the north.

A curious condition is found throughout this region. Along this entire course the canyon is apparently cut down through the harder rocks and is altogether in them, but at a distance of not more than 1 or 2 miles to the southwest there is along its entire course a zone of faulting, the region to the west having evidently dropped for a distance of several thousand feet, so that the entire Uncompahgre Valley is in the Colorado shales. There is, then, commencing at Gunnison Canyon, first a high ridge, consisting principally of granite, gneiss, and mica-schists, then a comparatively level tract, known as Bostwick Park, terminating to the southwest in a succession of shale and adobe ridges and valleys. By the shortest line the distance from the water level on the Gunnison side to a corresponding level in Uncompahgre Valley averages between 7 and 8 miles, and a survey was made of as much of this region as was necessary to find the shortest possible line by means of which a sufficient tract of land in Uncompahgre Valley could be covered to make the project profitable.

The Vernal Mesa is cut to a considerable extent by ravines and ridges, the general elevation being about 8,000 feet and the limits of elevation approximately from 7,000 to 9,000 feet. The surface is generally covered with oak brush, buck brush, piñon, and cedar, and higher up some aspen and spruce. A considerable portion of the highest ridge is so level that it would seem impossible to a person traversing it that there could be a canyon there, and one comes suddenly to the very edge of a fissure approximately a half mile in depth. Bostwick Park, or the level tract southwest of the main ridge, is, approximately, 7 miles in length and varies in width from a half mile to 2 miles. In about the center of it there is an old lake bed which holds about a foot of water during a portion of the year. The drainage from Bostwick Park, comprising the greater part of the drainage of the entire Vernal Mesa, breaks through the main ridge by means of a canyon, known as the Red Rock Canyon, and flows into the Gunnison. There are upon the mesa, generally along the fault between the two formations, a few springs of water, most of them of inconsiderable size and drying up in the latter part of the year, but one in the Red Rock Canyon is a perennially flowing spring of considerable volume and of excellent water. A few small log cabins have been built upon the summit of the mesa by prospectors, and a passable road from Montrose reaches the summit, so that parties can drive in carriages to the very edge of the canyon. The mesa runs out to a point near the mouth of the North Fork, the country to the west being of a generally level nature. Water can not be taken from the Gunnison below this point, however, owing to the comparatively slight fall of the stream.

METHODS OF SURVEY.

A party of six men was placed in the field by the Survey in June, 1901. Camp was made on the top of the Vernal Mesa, the region to be surveyed. Work was continued without cessation throughout the month of June and in July. The topographic mapping was placed under the supervision of Mr. Jeremiah Ahern and was completed September 30. Mr. A. L. Fellows was in charge of the engineering features, and ran three level lines across the mesa to the water's edge. He also made special examination of the bottom of the canyon, which had never been explored. In this he was accompanied by Mr. W. W. Torrence. On October 17 and 18, 1901, an examination of the geology of the region was made by Mr. Whitman Cross, of the Geological Survey, for the purpose of ascertaining the formations which would be penetrated by a tunnel piercing the divide by the shortest possible line, and his report is appended (pp. 148 to 149). The line was determined by means of the topographic survey, Mr. John A. Curtis, deputy State engineer, cooperating in making the location and acting as supervising engineer for the State of Colorado in preliminary construction work. For the latter purpose $25,000 was appropriated by the Colorado legislature, a supervising board was appointed, a road to the south end of the tunnel was constructed, and work on a tunnel line was commenced.

From the topographic survey and the triangulated line run by Mr. Curtis the State tunnel board decided that the most feasible line for a tunnel is that shown on the accompanying plat (fig. 17). This consists of two parts, the longer and lower portion being a tunnel about 4 miles in length, starting about 8 miles northeast of Montrose and running in a nearly true northeast direction. Owing to the elevation at which it would be necessary to locate this tunnel in order to cover the lands to be irrigated, this portion would join the canyon considerably above the bed of the river, and the line would therefore have to be continued up the stream a distance of approximately 2 miles in order to reach the grade of the stream, this portion consisting of a tunnel extending through a spur of the mountain.

In order to supply Uncompahgre Valley approximately 1,200 second-feet will be necessary at the times of greatest demand. With the fall available—about 10 feet to the mile—this will require an opening of

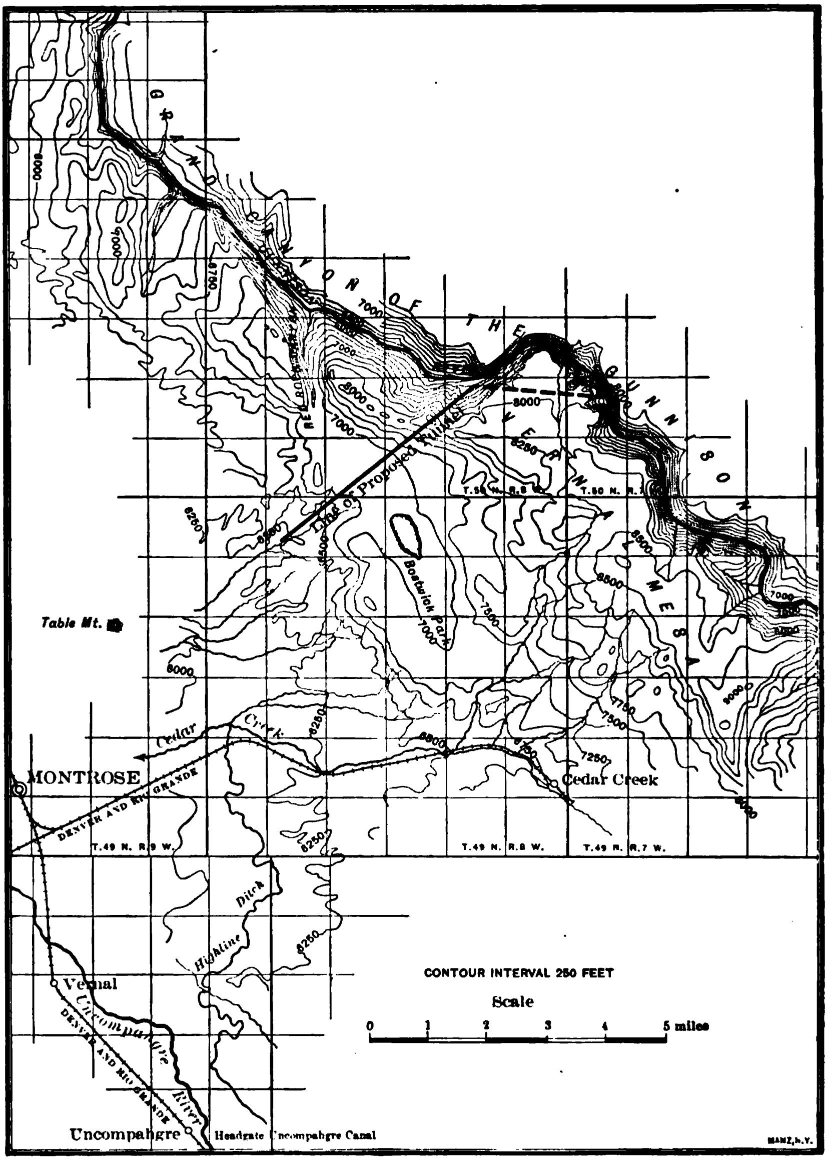

FIG. 17.—Contour map of the vicinity of the proposed Gunnison tunnel, Colorado.

at least 12 by 12 feet clear, with smooth walls. As probably 2 miles of the main tunnel will pass through shale, this portion must be lined. In the remainder of the tunnel the formations will undoubtedly be hard enough to withstand the action of the water without protection.

A comparison with tunnels constructed under similar conditions in Colorado and adjacent States indicates that excavation for a tunnel 31,500 feet long with a cross section of 12 by 12 feet should cost not to exceed $20 per foot, making a total cost of approximately $630,000; but as it will be necessary to line probably 2 miles of the interior of the tunnel, $250,000 should be added to this sum, making a total cost of $880,000 for the tunnel. To this amount there should also be added the sum of $200,000 for the necessary dam, controlling works, engineering, and contingencies, making the total for the completed tunnel approximately $1,080,000. The State board of control, appointed by the governor of Colorado to oversee the work of the State, has also caused an estimate to be made by Mr. Thomas R. Henahen, an experienced tunnel superintendent. This estimate places the amount necessary for the construction, not including lining, dam, controlling works, or engineering, at approximately $580,000, including the cost of the power plant required. Before water can be made available for use distributing canals must be purchased or constructed, which may cost approximately $1,500,000 additional. The latter, however, may not be considered as a part of the expenditure for the diversion of water into Uncompahgre Valley, as the residents of the valley might provide for the distribution of water if the diversion is made. It is probable, however, that it will be found desirable to plan a comprehensive distributing system in connection with the main lines.

WATER SUPPLY.

In considering the tract of land to be irrigated questions arise as to the amount of water at present available and the area of the arable lands. As has previously been stated, the Uncompahgre River flows through the valley and is the natural source of supply for the irrigable lands. Unfortunately, the discharge of the river is not sufficient to furnish water for more than one-sixth of the lands of the valley. For a number of years a gaging station was maintained by the Geological Survey at a point below the principal tributaries of the river and above the head gates of the larger irrigating canals taking water from the same, the station being located about a half mile east of the Denver and Rio Grande Railroad station at Fort Crawford. This station has been described in detail, and the records of gage heights and discharge have been published in various reports. The table on page 140 gives the general results of gaging and gage heights. From this table it will be seen that the maximum average discharge of the stream at the gaging station is in June, the average of the five years 1895 to 1899, inclusive, amounting to 802 cubic feet of water per second, the maximum stage varying from May 27 to June 28. The discharge rapidly falls away, however, after the maximum stage is reached, so that the average discharge for July was 361 second-feet, and for August, September, October, and November 140, 104, 109, and 87 second-feet, respectively.

Discharge of Uncompahgre River at Fort Crawford (Uncompahgre post-office), Colo.

Month.	1895.[a]	1896.[b]	1897.[c]	1898.[d]	1899.[e]	Mean discharge.	
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Acre-ft.*
April	......	......	386	327	263	325	19,338.84
May	......	1,010	787	306	534	659	40,520.33
June	1,082	519	994	704	709	802	47,722.31
July	470	126	527	430	252	361	22,197.02
August	277	38	136	111	138	140	8,608.26
September	117	148	146	67	41	104	6,188.43
October	70	106	204	58	......	109	6,702.15
November	82	86	127	54	......	87	5,176.86
December	112	......	......	......	......	112	6,886.61
Means and total.	315	290	413	257	323	300	[f] 163,340.81

Year.	Maximum discharge.		Minimum discharge.	
	Date.	Amount.	Date.	Amount.
		Sec.-ft.		*Sec.-ft.*
1895	June 28	1,535	Nov. 6	55
1896	May 27	3,375	Aug. 15	10
1897	June 15	1,467	Sept. 1	55
1898	June 24	985	Aug. 3	15
1899	June 15	1,163	Sept. 10	4

[a] Record from June 25 to Dec. 31, inclusive.
[b] Record from May 1 to Nov. 30, inclusive.
[c] Record from Apr. 1 to Nov. 27, inclusive.
[d] Record from Apr. 10 to Nov. 30, inclusive.
[e] Record from Apr. 2 to Sept. 30, inclusive.
[f] The number of acre-feet in an average year from Apr. 1 to Dec. 31. For a full year it would probably be safe to add 12,000 acre-feet, making a total of about 175,000 acre-feet for an average year.

At the present stage of irrigation in Uncompahgre Valley the average for July may be considered the limit of discharge that can economically be utilized for irrigation. There are few reservoirs of importance in the valley, so that but little water can be stored, and the crops are usually of such character—largely fruit, alfalfa, and other crops requiring late irrigation—that it is not profitable to farm unless there is a late water supply. It is probably within bounds to state that less than 30,000 acres can be irrigated in the average year by the present available water supply. It is true that probably twice that amount could receive one irrigation, but that would be insufficient for profitable farming.

The supply furnished by the Uncompahgre can and eventually will be augmented by an additional discharge derived from Cimarron River by means of the Cimarron ditch, which is now being constructed and will probably be available within the next year; but the amount of water that will be derived from this source will probably not exceed what can profitably be utilized on the tillable lands above any possible elevation that could be reached by the main canals of the valley. This source of supply is therefore practically eliminated, so far as the tract here under consideration is concerned.

The water supply always begins to fall short in the latter part of June, and from that time on there is always a deficiency, even under existing conditions, so that it would be unreasonable to suppose that there would be any extended additions to the irrigated area of the valley unless additional water were obtainable.

No other gaging station than that at Fort Crawford has been regularly maintained upon Uncompahgre River, and, in fact, any other would be of no material assistance in determining the available supply, as during the greater portion of the irrigation season the stream is practically dry along its lower course, except a little seepage water, which is taken out about as fast as it returns to the stream.

The table below gives a list of the discharge measurements made at the Fort Crawford gaging station during the time records were kept at that point. It will be seen from this table that by actual measurement the discharge was at one time—August 21, 1896—as low as 31 second-feet, and at a number of times subsequent to that date it was considerably less than 100 second-feet at periods when an abundant supply of water was needed.

Discharge measurements of Uncompahgre River at Fort Crawford (Uncompahgre post-office), Colo.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*		*Sec.-ft.*
June 25, 1895 [a]	834	Oct. 18, 1896 [a]	95	May 9, 1898 [b]	203
Aug. 26, 1895 [a]	218	Apr. 18, 1897 [a]	487	June 15, 1898 [b]	720
Oct. 7, 1895 [a]	89	May 10, 1897 [a]	884	Aug. 12, 1898 [b]	74
Nov. 18, 1895 [a]	92	June 21, 1897 [a]	1,081	Oct. 16, 1898 [b]	56
May 11, 1896 [a]	568	July 19, 1897 [a]	473	Apr. 16, 1899 [b]	328
June 15, 1896 [a]	560	Aug. 23, 1897 [a]	70	May 15, 1899 [b]	747
July 18, 1896 [a]	204	Sept. 20, 1897 [a]	153	June 19, 1899 [b]	773
Aug. 21, 1896 [a]	31	Oct. 18, 1897 [a]	195	Sept. 21, 1899 [b]	69
Sept. 21, 1896 [a]	122	Apr. 5, 1898 [b]	91	Nov. 20, 1899 [b]	79

[a] Gagings made by F. Cogswell.

[b] Gagings made by A. L. Fellows.

The following table gives a few discharge measurements made at Montrose, which may be considered approximately the center of the irrigation district. . From this table it will be seen that the discharge at Montrose is practically nothing during a considerable portion of the irrigation season. The last gaging given in this table was made at Delta, near the mouth of the stream, and shows practically no discharge.

Discharge measurements of Uncompahgre River at Montrose, Colo.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*		*Sec.-ft.*
Sept. 20, 1899[a]	15	Aug. 10, 1900[a]	2	Oct. 21, 1901[b]	13
Nov. 20, 1899[a]	15	May 20, 1901[a]	1,083		
July 5, 1900[a]	150	July 13, 1901[a]	192		

[a] Gaging made by A. L. Fellows.

[b] Gaging made by A. L. Fellows at Delta.

These tables exhibit clearly that, when compared with the amount of land susceptible of irrigation, which are given on pages 146–147, the available supply of water is totally inadequate to the demands. Moreover, the supply is constantly becoming less, owing to the fact that the hillsides which form the watershed are becoming more and more denuded of timber, and the irrigating ditches along the upper part of the stream are constantly making more and more use of the water decreed to them, so that less comes down to the canals below.

On Gunnison River the only gaging station maintained above the point at which water can be diverted for the purpose of irrigating Uncompahgre Valley is at Iola, which is approximately 50 miles farther upstream. The discharge of the river at that point, as shown by the records of the years 1900 and 1901—these being the only years in which records have been kept—is given in the table below. These two years, which may be assumed to be fairly average ones, show a maximum average discharge in May of 3,220 second-feet and a minimum discharge in November of 259 second-feet, the minimum stage commencing in September of each year.

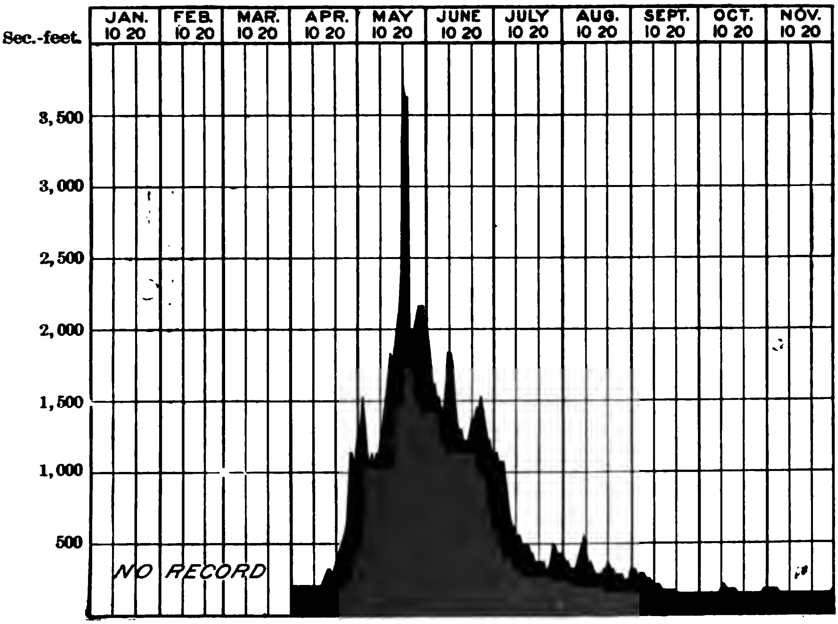

Fig. 18.—Diagram of discharge of Gunnison River at Iola, Colo., for 1901.

Discharge of Gunnison River at Iola, Colo.

Month.	1900.	1901.	Mean discharge.	
	Second-feet.	*Second-feet.*	*Second-feet.*	*Acre-feet.*
April	773	887	830	49,388
May	2,875	3,564	3,220	197,989
June	2,726	2,843	2,785	165,719
July	727	1,133	930	57,183
August	360	676	518	31,851
September	260	373	317	18,863
October	250	282	266	16,356
November	[a] 250	268	259	15,412
Means and total	1,028	1,253	1,141	[b] 552,761

Year.	Maximum discharge.		Minimum discharge.	
	Date.	Amount.	Date.	Amount.
		Second-feet.		*Second-feet.*
1900	May 30	4,388	Sept. 4	250
1901	May 20	5,580	Sept. 20	255

[a] Estimated.

[b] Total acre-feet discharged in an average year from Apr. 1 to Nov. 30, inclusive. It would probably be safe to add about 60,000 acre-feet for the discharge of the winter months, giving a total discharge of about 613,000 acre-feet in an average year.

Several streams enter Gunnison River between Iola and the point where water could be diverted from the river, these being Elk, West Elk, Sapinero, Currecanti, and Crystal creeks on the north side of the river and Cebolla, Lake Fork, Blue, and Cimarron creeks on the south side. A comparison with gagings made and records kept below the mouth of the canyon shows that it may safely be assumed that the supply at the head of the proposed tunnel would be between two and three times the discharge at Iola. For example, on October 22, 1901, when there was a discharge at Iola of but 255 second-feet, there was a discharge about 6 miles above Delta of 605 second-feet, approximately the amount that would have been available for the tunnel had it been required.

The amount needed diminishes rapidly after the 1st of August, and in the latter part of the irrigation season there is usually required less than half the supply that is necessary during the earlier part of the season. The supply furnished by Gunnison River during an average year would be ample for the irrigation of about 100,000 acres more than are now irrigated.

The table below gives the discharge of Gunnison River near its mouth, at Grand Junction. This is far below the tract of land considered in this report, but it is of interest in this connection as showing that the low-water stage is ample for all requirements. It is probable that during the low-water periods there is a loss instead of a gain between Delta and Grand Junction, owing to the slight fall of the stream and the sand bars through which the water percolates.

Discharge of Gunnison River at Grand Junction, Colo.

Month.	1897.[a]	1898.[b]	1899.[c]	Mean discharge.	
	Second-feet.	*Second-feet.*	*Second-feet.*	*Second-feet.*	*Acre-feet.*
April			3,550	3,550	211,240
May	16,282	5,318	10,296	10,632	653,736
June	12,263	8,850	12,380	11,164	664,304
July	4,410	2,543	4,349	3,765	231,501
August	991	689	1,921	1,200	73,785
September	482	479	875	612	36,417
October	1,598	533		1,062	65,300
November	742	497		619	36,834
December	458			458	28,161
Means and total	4,653	2,701	5,561	3,674	[d]2,001,278

[a] Record from May 2 to Dec. 4, inclusive.
[b] Record from May 1 to Nov. 30, inclusive.
[c] Record from Apr. 1 to Sept. 30, inclusive.
[d] Total acre-feet in eight average months.

Discharge of Gunnison River at Grand Junction, Colo.—Continued.

Year.	Maximum discharge.		Minimum discharge.	
	Date.	Amount.	Date.	Amount.
		Second-feet.		*Second-feet.*
1897	May 9	19,834	Aug. 28	172
1898	June 4, 19	11,361	Nov. 15	311
1899	May 16 June 14	16,750	Sept. 30	758

The following table gives the actual gagings made at Iola.

Discharge measurements of Gunnison River at Iola, Colo.

Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*
May 3, 1900	1,272	Aug. 25, 1900	392
June 28, 1900	1,658	Apr. 11, 1901	388
July 5, 1900	1,169	May 17, 1901	4,005
Aug. 9, 1900	431	July 29, 1901	836

NOTE.—All gagings made by A. L. Fellows.

The following table shows the gagings made below Iola. The next to the last gaging was made at Whitewater and the last above Delta, but they are classed with the Grand Junction measurements, being below the canyon and at points below which relatively little additional water flows into the main stream.

Discharge measurements of Gunnison River at Grand Junction, Colo.

Date.	Discharge.	Date.	Discharge.	Date.	Discharge.
	Sec.-ft.		*Sec.-ft.*		*Sec.-ft.*
Oct. 17, 1894 [a]	748	Oct. 27, 1897 [d]	1,270	May 13, 1899 [e]	14,280
June 28, 1895 [a]	4,178	Nov. 23, 1897 [b]	828	June 18, 1899 [e]	12,769
July 17, 1895 [a]	2,642	Apr. 26, 1898 [e]	5,932	Sept. 19, 1899 [e]	1,061
Oct. 1, 1895 [a]	781	May 23, 1898 [e]	4,647	Nov. 18, 1899 [e]	968
Apr. 20, 1897 [b]	5,975	June 28, 1898 [e]	5,274	Mar. 20, 1900 [e]	1,477
May 20, 1897 [c]	16,644	Aug. 27, 1898 [e]	866	July 7, 1900 [e]	2,121
July 28, 1897 [d]	1,814	Oct. 15, 1898 [e]	578	May 2, 1901 [f]	20,176
Sept. 28, 1897 [d]	1,246	Apr. 15, 1899 [e]	3,002	Oct. 22, 1901 [g]	605

[a] Gaging made by A. P. Davis.
[b] Gaging made by C. C. Babb.
[c] Gaging made by W. B. Dougall.
[d] Gaging made by F. Cogswell.
[e] Gaging made by A. L. Fellows.
[f] Gaging made by A. L. Fellows at Whitewater.
[g] Gaging made by A. L. Fellows above Delta.

The water supply of Gunnison River will not be needed for lands along that stream, for the amount of irrigable lands is so small that they can not utilize more than a small fraction of the total discharge. The water needed for these small areas can probably be entirely supplied by the streams entering the Gunnison below the proposed mouth of the tunnel, such as the North Fork and Smiths Fork. The laws of Colorado fully cover this point, making the prior use of water the basis for prior rights, so that it makes no difference where land is first reclaimed, provided the water is used advantageously.

IRRIGABLE LANDS.

The lands of Uncompahgre Valley may be divided into three classes: (1) Cultivated lands; (2) lands under ditch, but not irrigated, because of an insufficient supply of water; and (3) lands above existing canals. More generally classified, however, we may consider them as (1) lands already under private ownership and (2) lands still belonging to the United States and subject to entry.

In the neighborhood of Montrose about 118,000 acres of land have been filed upon, and about 80,000 acres, all under the proposed canal lines, still remain vacant. Of the 118,000 acres, however, probably not more than 30,000 acres are under cultivation, leaving about 90,000 acres without water. Of the vacant lands still remaining, a very great part is above existing canals, but might be covered if the system of canals contemplated were to be constructed.

A topographic survey of the entire valley has not been made, so that nothing more than an approximate estimate of the available irrigable lands is possible. Of the 118,000 acres already filed upon and the 80,000 still vacant, there is a large portion, consisting of high land among rolling hills, which can not be cultivated. Another considerable portion consists of lands which have by seepage either already been rendered alkaline, and consequently undesirable for cultivation, or would become so if water were put upon higher lands in their vicinity. In a general way, we can say there remains a total of about 100,000 acres that can be reclaimed below the highest point reached. Of this probably 60,000 acres are lands already filed upon, the remaining 40,000 being Government lands. It must be borne in mind that these estimates are merely approximate, but they are probably nearly correct. In this connection the following letter from Mr. Sterling S. Sherman, superintendent of the Montrose canal, the largest canal of that district, is of interest:

> In reply to your inquiry concerning the Montrose canal and the land covered by it and the irrigation thereof, you are informed that the Montrose canal is about 30 miles long and now has in the neighborhood of 50 miles of laterals, some of its laterals having been abandoned in recent years; that the canal system covers about 40,000 acres of irrigable lands which can be irrigated from it; that there are probably

over 200 farms of 160 acres each which have been patented and to some extent farmed with water from this canal; that in the early years of farming under the canal there was more water furnished to irrigators by the canal and more land farmed than there has been in recent years. In the years 1888 and 1889 water was purchased for between 16,000 and 18,000 acres of land, but since those years the supply has not been sufficient for near the acreage above mentioned, and many farmers have left their farms, no work being done upon them. In the last few years only 8,000 or 9,000 acres have been farmed by waters from the canal, and the water supply has not been sufficient to irrigate near the amount of land that was irrigated in former years. I can see no reason why, with sufficient water, the whole of the land under Montrose canal could not be farmed.

Similar statements might be made with equal truth by all the other canal owners and managers of Uncompahgre Valley.

An important feature is that if sufficient water were furnished to Uncompahgre Valley at a point as high as is contemplated in the survey, a part of the present available supply could be utilized on vacant lands above. This would be of special advantage, as the return from seepage is considerable in this valley. It is probable that an additional 10,000 acres might be reclaimed in this way, this acreage being about equally divided between lands now under filings and those still unclaimed. The value of the lands reclaimed would be raised at once from the nominal sum of $1.25 per acre to not less than $50 per acre, and after a few years much of the land would be worth much more.

From the foregoing statements we may briefly summarize as follows:

(1) The proposition of constructing a tunnel to convey water from Gunnison River to Uncompahgre Valley is feasible, and the water supply is sufficient.

(2) The construction of the tunnel would result in the reclamation of more than 40,000 acres of vacant Government land and 60,000 acres of land already filed upon, a total of 100,000 acres.

(3) The cost of the tunnel alone would be about $850,000, and a distributing system might also be required, costing $650,000 in addition, making a total cost of $1,500,000.

(4) The resulting increase in values would be not less than $5,000,000.

(5) Enough land would be reclaimed to make homes for at least 1,200 families.

In conclusion it should be stated that all estimates given are but roughly approximate, only the topographic survey and the geologic examination having been completed. It remains for exact surveys to be made for the purpose of finally locating the tunnel line and canal system to the best possible advantage, and of definitely determining the amount of land that will be benefited and the increased wealth that will be created by means of the proposed system.

GEOLOGIC STRUCTURE.[a]

The geology of the proposed tunnel route is in general very simple. Gunnison Canyon is cut into a complex of granite, gneiss, and various schists, with dikes of pegmatite here and there. Uncompahgre Valley is, on the other hand, excavated for the most part in nearly horizontal, soft Cretaceous shales. The high ridge of general northwest-southeast trend between the two drainages, called the Vernal Mesa, beneath which the tunnel is to pass, is mainly composed of the same complex of crystalline rocks that is exposed in Gunnison Canyon, with a profound fault on its southwest slope, by which the Cretaceous shales and the lower sedimentary rocks have been brought to abut against the ancient granites, gneisses, etc.

From this general statement it is clear that the tunnel, the general course of which is at right angles to the ridge of the Vernal Mesa and to the fault, will, after leaving the canyon, first traverse the crystalline complex as far as the fault line, beyond which, to its mouth, it will pass through sedimentary rocks. The location and character of the fault line and the nature of the stratified rocks on its southwestern side are the chief questions upon which information is needed. The granites, gneisses, and various schists to be traversed by the tunnel from its entrance to the fault line will undoubtedly present the same diversity seen in the canyon and in the exposures on the Vernal Mesa. Granite and gneiss probably constitute by far the greater part of the rock mass. The surface exposures do not afford sufficient evidence for detailed estimates of the changes in character to be met with at the tunnel level.

The Vernal Mesa fault can not be very accurately located on the tunnel line because of the amount of coarse bowlder or gravel material, together with débris from the ridge above, which obscures the rock in place at the fault crossing. It is known, however, that the gravels of Bostwick Park are for the most part underlain by Cretaceous shales, and the fault line must cross the course of the tunnel very nearly at the base of the steep slope, as represented in the accompanying profile section (fig. 19).

At the extreme northwestern end of Bostwick Park bench, at the head of Red Rock Canyon, a point somewhat more than a mile from the tunnel line, the main fault bordering the granite was very accurately determined. It was there a sharply defined plane dipping south-southwest at a very steep but more or less variable angle. It was traced from that point northwesterly for more than a mile. But the observations made in that vicinity show that the fault is not a simple one, but that there is a fractured zone which at the line of the tunnel is probably more than 1,000 feet in width between the two principal fracture planes. It is therefore probable that the tunnel, on passing the main northeastern fracture of the fault zone, will pass into more or less disturbed sandstones, shales, and impure limestones belonging to the Jurassic formations underlying the Cretaceous in this region. To the southwest of the fault zone it is probable that the tunnel will at once pass into the Mancos shales and continue in them to its mouth. From the nature of these shales, however, it is impossible to ascertain with certainty how much they are upturned adjacent to the fault zone. The observations made indicate that there is a variable southwestern dip in the shales near the fault line. Should this be the prevalent structure in depth, it is possible that at the tunnel level, which is 700 feet or more below the level of Bostwick Park, the underlying Dakota sandstones may, by the upturning, be brought against the fault. In that case the tunnel might pass for some distance through gently dipping sandstones of the Dakota before the dip would bring the base of the shales to the tunnel level. The accompanying profile section (fig. 19) exhibits in a graphic way the estimated position of the Vernal mesa fault and the character of the formations which the tunnel will probably encounter on either side of it.

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[a] From report of Whitman Cross, geologist.

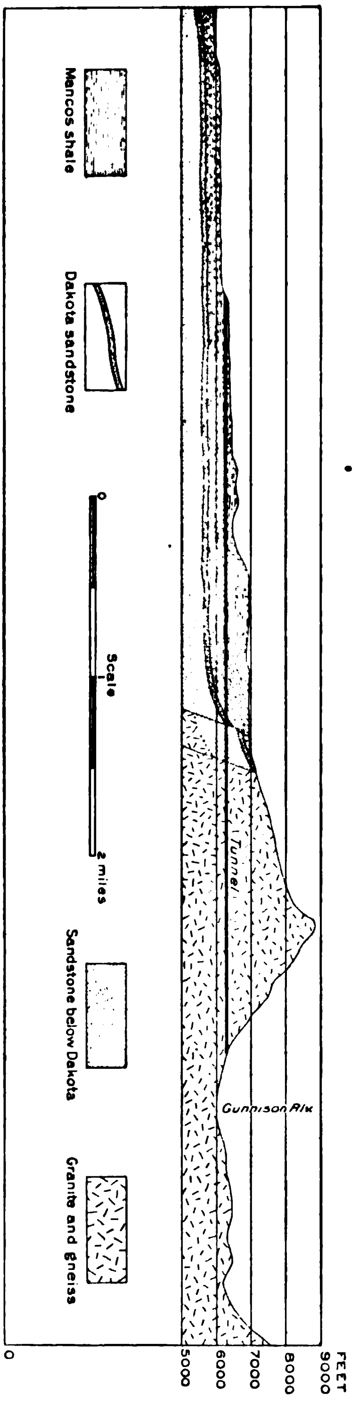

FIG. 19.—Profile section showing probable position of Vernal Mesa fault and character of formations which will probably be encountered by the proposed Gunnison tunnel.

GRAND RIVER DIVERSION.

Grand River receives a large perennial supply of water from the high mountains of central Colorado. It flows in a general southwesterly and westerly course into Utah, where it joins Green River to form the Colorado. The valleys along its course are for the most part narrow, and the water supply appears to be largely in excess of the demands likely to be made upon it. In the summer season, however, the river sometimes diminishes to a discharge of less than 800 cubic feet per second above Grand Junction. At this point it receives the flow from Gunnison River, described in the preceding pages.

For a number of years it has been believed that the waters of Grand River could be diverted at some point above the mouth of the Gunnison and carried out on the north side of the river by a large canal extending into Utah and irrigating the lands both in Colorado and in Utah. Preliminary surveys have been made by individuals at one time or another which tend to confirm this belief, but the expense of obtaining precise information for a large project of this kind has been so great that the conclusions are open to doubt. The most important of these early surveys was that made by Mr. C. D. Page, of Greeley, Colo., in the spring of 1897. He reported to Messrs. George Smith and Alexander Strothers upon what is known as the Plateau Grand canal. This survey was begun on April 3 and continued until June 2, 1897. Mr. Page was assisted by a rodman, two chainmen, and a flag man. The lands to be irrigated, in all about 80,000 acres, are on the right bank of Grand River, extending from the mouth of the canyon above Grand Junction westerly to the State line. To obtain sufficient elevation to bring water to this point, it was found necessary to make the head of the canal 6 or 7 miles above the point where the river leaves the canyon. It was considered by Mr. Page impossible to place the canal and its head on the right bank of the river. The Rio Grande Junction Railway is located on that side, and there is in many places hardly space for the roadbed between the river and the high rock walls. This railroad is used jointly by the Colorado Midland and the Denver and Rio Grande railroads. On the opposite or left bank of the river in the canyon is the county road from Grand Junction to Plateau Valley, and also an uncompleted ditch known as the Smith and Strothers.

The point selected by Mr. Page for the head of the proposed Plateau Grand canal was at a precipitous wall of rock on the left side of the river, about 1,000 feet downstream from the railroad tunnel in the canyon. He proposed to make at the head a solid rock cut for 600 feet, the canal then being on an earth bottom 6 feet above high-water mark, upon which it continues for 1,000 feet, and at a safe distance from the water's edge.

At about 4,500 feet from the head on Grand River, Mr. Page proposed to cross Plateau Creek on grade and to place a dam across the stream, with an ample spillway and flood gates. The water of this creek is usually clear and could be used when Grand River is carrying large quantities of mud. Below the crossing of Plateau Creek the canal line ran along the county road, skirting steep slopes. At 7,000 feet from the head the precipitous walls approach so near the river that it was considered necessary to plan for a flume 300 feet long, providing this with spillway and sand chute. Other flumes were estimated for at 24,300 and 28,900 feet from the head.

Rapid Creek, about 30,300 feet from the head, was planned to be crossed on a flume 120 feet long and 25 feet above the water. It was proposed to construct a feeder from this creek for use during the spring months when Grand River is in flood and its waters consequently are not desirable for domestic use.

The proposed canal crossed from the left to the right side of Grand River at the mouth of the canyon, this being about 35,200 feet below the head. The flume as planned was 1,160 feet long, 68 feet above the surface of the river, and 19 feet above the railroad track. This flume was to be supported by a steel truss, 200 feet long, spanning the river channel and resting on stone piers on each side. The remainder of the flume was to be supported by trestles and piling.

The length of the canal in the canyon is approximately 6½ miles. For about one-half this distance the canal line is on a steep mountain side, being made up largely of solid rock, upon which are occasional deposits of bowlders and gravel. The other half of the distance is on a surface relatively level, but broken by gullies and ridges. Most of the material to be excavated here is gravel or sand.

The canal line crossing Grand River at the mouth of the canyon runs along the foot of the Little Book Cliffs, over a surface well adapted to canal construction. It crosses the old Alta ditch, a continuation of the Smith and Strothers ditch, following it for about 3 miles over sunken ground, which has settled from 1 to 3 feet since the water was turned into it. This sinking of the ground when first covered with water has been found to be quite frequent in the upper Grand Valley, near the mountains. It occurs only on new ground, and usually continues for one or two seasons.

Continuing westerly the line swings away from the foot of the cliffs and crosses a country broken by high ridges of shale rock. The surface of this is decomposed and can be plowed and scraped. Below this is a soft blue shale which can not be moved without the use of powder or the pick. A grade line was continued, the terminus being about 1¼ miles from the summit of what is known as the Excelsior divide, about 3 miles east of the Utah line. No engineering difficulties were met with in this portion of the line, it being ordinary prairie work with an occasional flume crossing water courses. Most of these proposed flumes are short, ranging from 50 to 250 feet in length, none exceeding 400 feet.

At Prairie Creek, near Excelsior divide, Mr. Page's line is approximately 500 feet in elevation above Grand River and about 7 miles north of that stream. The top of the divide was found to be about 200 feet above his grade line. He states that it is practically impossible to take water on this grade through the divide in an open cut, but that it may be possible to pierce the divide with a tunnel. The lands beyond the State line in Utah are attractive in appearance, and with an ample supply of water from Grand River it should be feasible to extend the line to cover the lines in Utah. The estimate of the cost, made by Mr. Page, is as follows, being based on the following dimensions of the canal down to station 1029:

Width on the bottom, 35 feet, with side slopes in excavation 1 to 1; top of bank 10 feet above canal bottom, with a width of 12 feet on top and side slopes 1½ to 1. Slopes in gravel excavation, ½ to 1, with bottom width of 40 feet.

From stations 1029 down, the widths of canal on the bottom to be 30 feet for the first 15 miles, 20 feet for the next 10 miles, and 12 feet to the terminus.

The capacity of the canal from the head down to station 1029 would be 970 cubic feet of water per second, according to calculations based on Kutter's formula, using the coefficient 0.025; or 1,025 cubic feet per second according to calculations based on formula given in Trautwine, using coefficient 0.84.

From station 0 to 1029, north of Grand Junction:		
Solid rock, 84,306 cubic yards, at 80 cents	$67,445	
Shale, 67,100 cubic yards, at 20 cents	13,420	
Gravel, 505,019 cubic yards, at 10 cents	50,502	
Earth, 831,855 cubic yards, at 8 cents	66,548	
Flumes	95,946	
Grand River head gate	6,000	
Plateau Creek head gate and wasteway	5,000	
Rapid Creek head-gate	3,000	
		$307,861
From station 1029 to station 3482:		
Shale, 20,000 cubic yards, at 20 cents	4,000	
Earth, 1,025,000 cubic yards, at 8 cents	82,000	
Flumes and wasteways	40,000	
		126,000
Highway bridges, earthen pipe, culverts, etc		15,000
Engineering inspection and incidentals		67,000
Total cost		515,861

From the favorable conditions reported by Mr. Page and others it was considered desirable to make an examination of this locality, the matter being urged by citizens of Colorado and Utah. As a preliminary to the survey the lands were temporarily segregated under the terms of the reclamation law.

Field work was placed in charge of Mr. Gerard H. Matthes, assistance and advice being given at the outset by Mr. A. J. McCune, State engineer, the latter being a resident of Grand Junction and thoroughly familiar with the various projects. It was considered advisable to make the survey sufficiently broad to cover a number of alternatives regarding the location of the canal in the canyon. Although it seems impracticable to place the canal on the same side as the railroad, an inspection of the ground with this in mind indicated that such a construction might be possible by tunneling in several places.

Instead of keeping the canal along the bank of the river it is apparent that some advantage might be gained by locating it in Plateau Creek, lowering the bed of that stream, and diverting water from a loop of Grand River, which is cutting its way toward the valley of Plateau Creek. The topographic conditions are peculiar and can be well understood only by a good contour map. In fact, when the situation is gone over with various alternatives in mind, it is seen that although the canal is confined to a canyon there are many propositions which should be considered in a thorough examination.

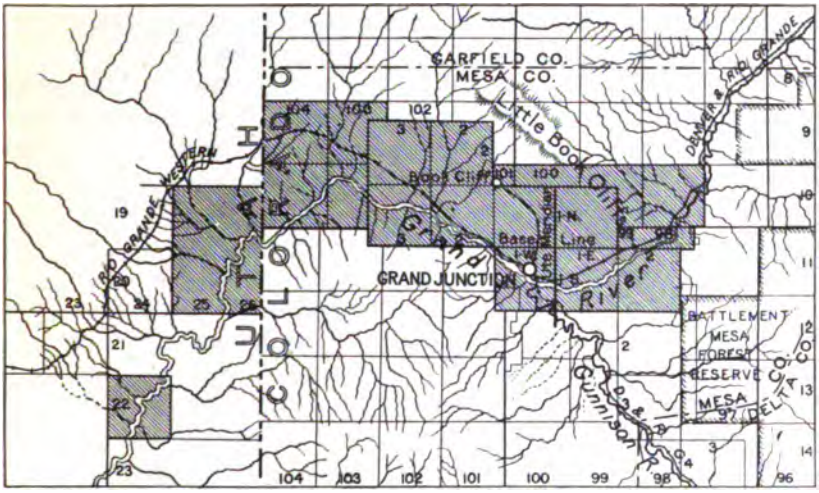

FIG. 20.—Map of lands temporarily withdrawn pending survey of the Grand River project, Colorado.

In order to obtain data upon which to decide the various suggestions, a detailed topographic map was made of Grand River, extending several miles above the railroad tunnel, and also of Plateau Creek; this was continued down the river on both sides to include the cliffs and mesa on the left or south bank, in order to demonstrate the practicability of taking out water to the excellent lands on that side.

The field work is in progress at the time of writing this report. A contour map on the scale of 2 inches to the mile is being prepared of the canyon of Grand River from a point above Tunnel railroad station, extending down on both sides of the river and including the lower portion of Plateau Creek. This line of topographic mapping is to be extended along the foot of the cliffs north of Grand River to cover all possible locations of a diversion canal and extend to or across the Excelsior divide on the Utah line.

STERLING PROJECT.

South Platte River receives its waters from the high mountains of central Colorado, the stream flowing northeasterly from the mountains and passing through the city of Denver. Various tributaries enter the river in its northerly course along the Rocky Mountain front, the principal one being Cache la Poudre Creek, on which the city of Greeley is situated. Near the junction with this creek the river turns abruptly toward the east and continues through the high plains of Colorado, passing out of the State in the northeast corner.

The waters of all of the tributaries of South Platte River and of the stream itself are used more or less completely in the irrigation of lands in or adjacent to the foothills. The extent of the land thus utilized probably surpasses that of any similar locality in the State. Practically all of the summer flow is diverted from the streams, and the South Platte is usually dry in the lower part of its course during a great part of the year. In winter and early spring, however, there is usually a considerable flow.

Measurements of the South Platte River and its principal tributaries have been carried on for several years in cooperation with the State engineer. The results of these show the amount of water coming from the mountains and also that which returns to the river by seepage or escapes during times of flood. The amount is considerable, and it has long been a question whether it would not be practicable to take out of the lower course of the river the water otherwise wasted and utilize it on the fertile lands which extend for many miles on both sides of the river. A number of preliminary surveys have been made for projects of this character, the general scheme being to provide a large diversion canal taking the flood water into depressions or artificial reservoirs, where it can be held for use during the crop season.

In December, 1900, Mr. A. L. Fellows made an investigation to determine the possibility of storing water in reservoir sites which could be reached by means of canals from South Platte River. The plan, which he outlined from a careful study and considerable familiarity with the situation, was that of taking a canal out of the river at a point in the vicinity of the Cache la Poudre, the lowest tributary of the South Platte from the mountains, all of the mountain drainage being above this point. He was influenced in this selection by the certainty that if water were stored at points as high above the mouth as possible there would eventually be a very large return to the river from seepage and waste water, and thus a perennial flow could be relied upon at points lower down on the main stream, which supply might in turn be taken out for the purpose of irrigating other tracts of land in the vicinity of Julesburg.

Mr. Fellows had previously visited certain reservoir sites known to exist in the region north of Orchard, which is in the territory under consideration, and had noted as excellent reservoir sites Jackson Lake reservoir, with a capacity of 67,790 acre-feet, and Sanborn Draw reservoir, capacity 70,260 acre-feet, both of which had been surveyed and filed upon by private parties. He was also informed by persons familiar with the country that there were a number of other sites that would hold from 20,000 to 200,000 acre-feet of water.

On the 14th of December, 1900, he visited the country lying immediately below the mouth of Cache la Poudre Creek and determined to establish a gaging station at Kersey as the most suitable point for river measurements and records. There was apparently no difficulty in carrying a canal of reasonable size across the country north of the river. The opportunities for head gates are good and the soil is of excellent quality for canal construction.

At the time of the examination there were about 600 second-feet going to waste in the South Platte at Kersey, which amount is probably less than the normal winter flow, as the last season was an extremely dry one, and on that account the seepage and return waters had fallen off considerably. Records of previous years show that there have been available at times during some of the summer months as much as 2,000 or 3,000 cubic feet per second, and it was regarded as advisable that a proposition should be considered embracing the carriage of at least 2,000 cubic feet per second to the reservoirs under consideration, the most important of these being at Pawnee Pass, about 15 miles northwest from Sterling, Colo., which is among the reservoir sites that might possibly be reached by means of such a canal as that projected.

On December 20 and 21, 1900, accompanied by Mr. D. A. Camfield, Mr. Fellows visited the Pawnee Pass reservoir site. This had been surveyed by private parties—Messrs. D. A. Camfield and George H. West—and the results of their survey, which is believed to have been carefully and thoroughly made, gave a capacity of 285,696 acre-feet. It would take a canal about 90 miles long to reach this reservoir site. There would, however, be many difficulties in the way of construction, and it is quite probable that by means of a careful topographic survey enough reservoir sites might be found even before this was reached to take the entire capacity of the proposed canal.

Pawnee Pass reservoir site lies at the junction of three branches of Pawnee Creek. The country is a gently rolling prairie. In order to make a reservoir here a dam would have to be built between two buttes approximately a mile apart, sloping to the center, so that the deepest places would be at the water course itself. This water course is usually dry, but at times carries large volumes from rains and melting snow. The buttes are capped by sandstone strata, great fragments of which are broken off and lie scattered over the ground. If the dam should be built here, it would probably be of earth backed by rock. The expense would necessarily be great, but only a detailed survey could tell whether it would be too great for the advantages accruing. The advantages were considered to be sufficiently great to at least warrant a careful examination.

The amount of land that could be irrigated if water could be satisfactorily stored is practically unlimited, there being hundreds of thousands of acres of prairie lands of the finest quality susceptible of a high state of cultivation if only water can be brought to it. The following data were compiled concerning some of the reservoir sites that are known to exist under the proposed system. These figures are taken from surveys made and filed in the State engineer's office at Denver and from examination on the ground.

Estimated capacity of various reservoir sites near South Platte River, Colorado.

	Area.	Capacity.	
		Cubic feet.	Acre-feet.
	Acres.		
Sanborn Draw reservoir [a]	3,811	3,060,525,600	70,260
Orchard Reservoir	463	250,000	5,700
Jackson Lake reservoir [a]	2,987	2,952,932,400	67,790
Wildcat reservoir No. 1	270		2,000
Wildcat reservoir No. 2	670		9,000
Wildcat reservoir No. 3	650		7,900
Pawnee Pass reservoir [b]	6,896	12,444,903,680	284,685

[a] At the 45-foot contour.

[b] At the 100-foot contour.

In all of these reservoirs it may be said that the depth is to a certain extent arbitrary. The Pawnee Pass, for example, might be made 100 feet deep at the lowest place, or probably as much as 200 feet if desired, as it is simply a question of the height of the dam constructed. Nearly all of the reservoir sites of this region are to a certain extent natural sites—that is, they are natural basins which can be filled with water to be drawn off by means of cuts. Pawnee Pass site would, however, necessitate a dam from the very bottom.

Borings made at the Pawnee Pass site indicated that hardpan would be reached all the way across the valley within a few feet of the surface. In general, the material in this dam and in others would have to be earth which is of fairly good quality, but it is possible that it might be deemed best to make the Pawnee Pass dam a rock fill faced with earth. The rock is of massive sandstone and will hold and last well.

Upon the passage of the reclamation act the people of eastern Colorado, especially citizens of Sterling, the principal town in the area to be benefited, urged that careful examination be made to determine the feasibility of storing water at Pawnee Pass. It was obvious that there were large areas of arid land which might be reclaimed, much of this being still in the hands of the Government, and the principal questions to be solved were those relating to quantity of supply and cost of taking water to the various reservoir sites or to Pawnee Pass.

The matter of providing an adequate supply was found to be more complicated than at the time of the preliminary report made by Mr. Fellows, since Jackson Lake reservoir had been constructed and other storage localities utilized upon the tributaries of South Platte River. It was a serious question whether, after allowing water for these, there would be sufficient water to justify construction of other reservoirs farther down the valley. In order to determine this a survey was ordered, lands being temporarily withdrawn as shown by the accompanying sketch.

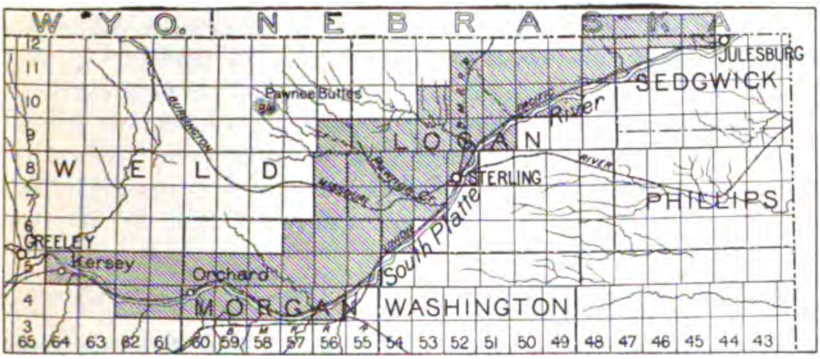

FIG. 21.—Map of lands temporarily withdrawn pending survey of the Sterling project, Colorado.

Mr. A. L. Fellows, in consultation with Mr. John E. Field, deputy State engineer, made plans for taking up the work, which was under the direct charge of Mr. C. T. Pease, of Denver, Colo.

A point of diversion was assumed on the north bank of South Platte River about 2½ miles north of the town of Kersey. The line examined was for a canal having a bottom width of 50 feet, average depth of 5 feet, and grade of 1.056 feet per mile from this point to Pawnee Pass. After examining this line for 13 miles it was found impracticable to carry it farther without making a drop of 30 feet. It is also demonstrated that between 5 and 6 miles of construction, mostly on the side hill and through sand, could be saved by taking a new point of diversion lower down the river and without the loss of any elevation at the point of discharge. Mr. Arthur P. Davis, who inspected the work, concurred in this opinion, and a new point of diversion was assumed about 3 miles northeast of the town of Hardin. From here

17.6 miles of new line were located through a rough country to the head of Sanborn Draw. A rough preliminary survey of the Sanborn Draw reservoir site was then made.

On the located lines bench marks have been established every half mile and elevations taken on each side of the line for a distance ranging from 50 to 300 feet, as the contour of the country necessitated.

The engineering difficulties as regards diversion of the waters do not appear from the work, as far as it has progressed, to be notably difficult, but the cost of construction and maintenance of a large canal through extensive areas of drifting sand renders the project one of doubtful expediency. The most serious matter, however, is in connection with the water supply, a study of which has been made during the time the field work has been in progress.

The rapid development of reservoir construction upon the headwaters of South Platte River and its tributaries threatens to cut deeply into the flood flow. Since the passage of the reclamation law and the interest excited by its discussion, a number of projects for storing water which had apparently been held in abeyance have been revived, the owners being stimulated to activity in order to secure the advantages which might otherwise be lost. There is no part of the West outside of California where reservoir construction has been carried to such an extent as in the vicinity of Greeley, and the success attained has encouraged associations of irrigators to utilize every basin which might be turned into an artificial lake. Many of these reservoirs have been built in 1901 and 1902. Those in operation and recently constructed are as follows:

Fossil Creek reservoir, from Cache la Poudre Creek and Mail Creek; capacity 490,000,000 cubic feet (11,259 acre-feet).

North Poudre reservoirs Nos. 7 and 8, from Cache la Poudre and North Fork of Cache la Poudre; capacity, 365,900,000 cubic feet (8,400 acre-feet).

North Poudre reservoirs Nos. 9 and 10, from Cache la Poudre, North Fork of Cache la Poudre, and Dry Creek; capacity, 635,000,000 cubic feet (14,578 acre-feet).

Mitchell's reservoir, from North Lone Pine Creek; capacity, 19,727,799 cubic feet (453 acre-feet).

Bijou Ditch Company's reservoirs, from South Platte River; capacity, 1,000,000,000 cubic feet (3,404 acre-feet).

In addition to these the following are contemplated or being constructed at the present time:

Larimer & Weld No. 2, from Cache la Poudre Creek; capacity, 360,000,000 cubic feet (8,264 acre-feet).

Beaver Lake reservoir, from Big Beaver Creek; capacity, 18,530,400 cubic feet (425 acre-feet).

Seven Lakes reservoir, from Big Thompson and Dry Creeks; capacity, 2,340,300,000 cubic feet (53,726 acre-feet).

Morgan County Company's reservoir, from South Platte River; capacity, 2,656,000,000 cubic feet (60,973 acre-feet).

New Empire reservoir, from South Platte River; capacity, 187,000,000 cubic feet (4,295 acre-feet).

Asa Sterling reservoir, from South Platte River; capacity, 75,533,000 cubic feet (1,734 acre-feet).

Jackson Lake reservoir, from South Platte River; capacity, 2,952,932,400 cubic feet (67,790 acre-feet).

Oasis reservoir, from South Platte River; capacity, 396,000,000 cubic feet (9,091 acre-feet).

Lower Latham reservoir, from South Platte River; capacity, 270,700,000 cubic feet (6,214 acre-feet).

Cheesman Lake reservoir, from South Platte River; capacity, 4,000,000,000 cubic feet (91,827 acre-feet).

Sanborn Draw reservoir, from South Platte River; capacity, 3,060,525,600 cubic feet (70,260 acre-feet).

The superintendent of Irrigation Division No. 1 states that "in the districts in the South Platte division there are, in addition to the above-mentioned reservoirs, 83 smaller ones, with capacities ranging from 60,000 to 100,000,000 cubic feet [1.4 to 2,300 acre-feet], which have been projected, and a great majority of them put into operation during the last two years." The aggregate amount claimed for these reservoirs would probably equal, if not exceed, that claimed for the first-named reservoirs.

There are already under construction two important reservoirs which lie along or near the proposed diversion line to Pawnee Pass.

Those reservoirs that are either already constructed or under way will draw the supply of water needed by them from the South Platte River in the immediate vicinity of the proposed diversion canal, and will require as much water as is shown to be available at the Kersey gaging station during the last two years. There would be required further for the filling of the Pawnee Pass reservoir an additional supply of not less than 2,500 second-feet for not less than five months, no part of which, so far as is shown by the records of the Kersey gaging station, can be obtained. When it is considered that canals below the mouth of the Cache la Poudre require for their use during the irrigation season at least 2,000 cubic feet per second, and that within the last two years there has been almost no time during the irrigation season when these ditches had any water except the seepage from the river, the gravity of the situation becomes at once apparent.

The projects already under way must have an ample supply of water for storage, and there are many thousands of acres under irrigating canals which can not be supplied even through the use of these new reservoirs. It has been argued, therefore, that it is inexpedient to endeavor to bring new lands under cultivation in this region. The figures appear to indicate that it is not desirable to attempt to fill the Pawnee Pass reservoir and irrigate additional arid lands until it is evident that there is an abundance of water for the present reservoirs and that the lands now under ditch have allotted to them a sufficient supply.

Estimates of water supply of most importance in this connection are those of the flow of South Platte River at Kersey, this being the nearest point to the proposed works of the Sterling project.

Estimated monthly discharge of South Platte River at Kersey, Colo.

[Drainage area 9,470 square miles.]

Months.	Discharge in second-feet.			Total in acre-feet.	Run-off.	
	Maximum.	Minimum.	Mean.		Second-feet per square mile.	Depth in inches.
1901.						
May	5,856	62	1,393	85,652	0.15	0.17
June	5,004	450	1,820	108,298	0.19	0.21
July	450	290	314	19,307	0.03	0.03
August	330	290	296	18,200	0.03	0.03
September	705	290	395	23,504	0.04	0.04
October	516	370	456	28,038	0.05	0.05
November	591	450	526	31,299	0.06	0.07
December	1,955	540	903	55,523	0.10	0.11
1902.						
January	807	591	677	41,627	0.07	0.08
February	845	646	727	40,376	0.08	0.08
March	705	330	510	31,359	0.05	0.06
April	310	25	140	8,331	0.015	0.02
May	271	25	118	7,256	0.01	0.01
June	1,885	100	185	11,008	0.02	0.02
July	591	100	153	9,408	0.02	0.02
August	138	100	107	6,579	0.01	0.01
September	2,631	80	363	21,600	0.04	0.04
October	325	170	249	15,310	0.03	0.03
November	527	224	326	19,752	0.03	0.03
December	637	475	532	32,711	0.06	0.07

IDAHO.

In Idaho irrigation has been developed mainly along Snake River and its tributaries in the southern or wider portion of the State. Toward the north the State lines converge and include a strip of high mountain area with narrow valleys, where the climate is semiarid, or even humid, the water supply large, and agriculture has developed rapidly without irrigation. In the south, however, the State extends across broad stretches of lava-covered plains upon which the rainfall is scanty, and the soil can not be successfully tilled without an artificial supply of moisture. In the northern or nonirrigated counties of the State over one-half of the acreage produces crops consisting largely of barley and wheat. In the southern portion the principal crops being raised under irrigation are alfalfa, hay, and grains cut green for forage, also orchard fruits, potatoes, and vegetables.

The total area irrigated in 1899 was a little more than 600,000 acres, being an increase of over 100 per cent in the preceding ten years. The

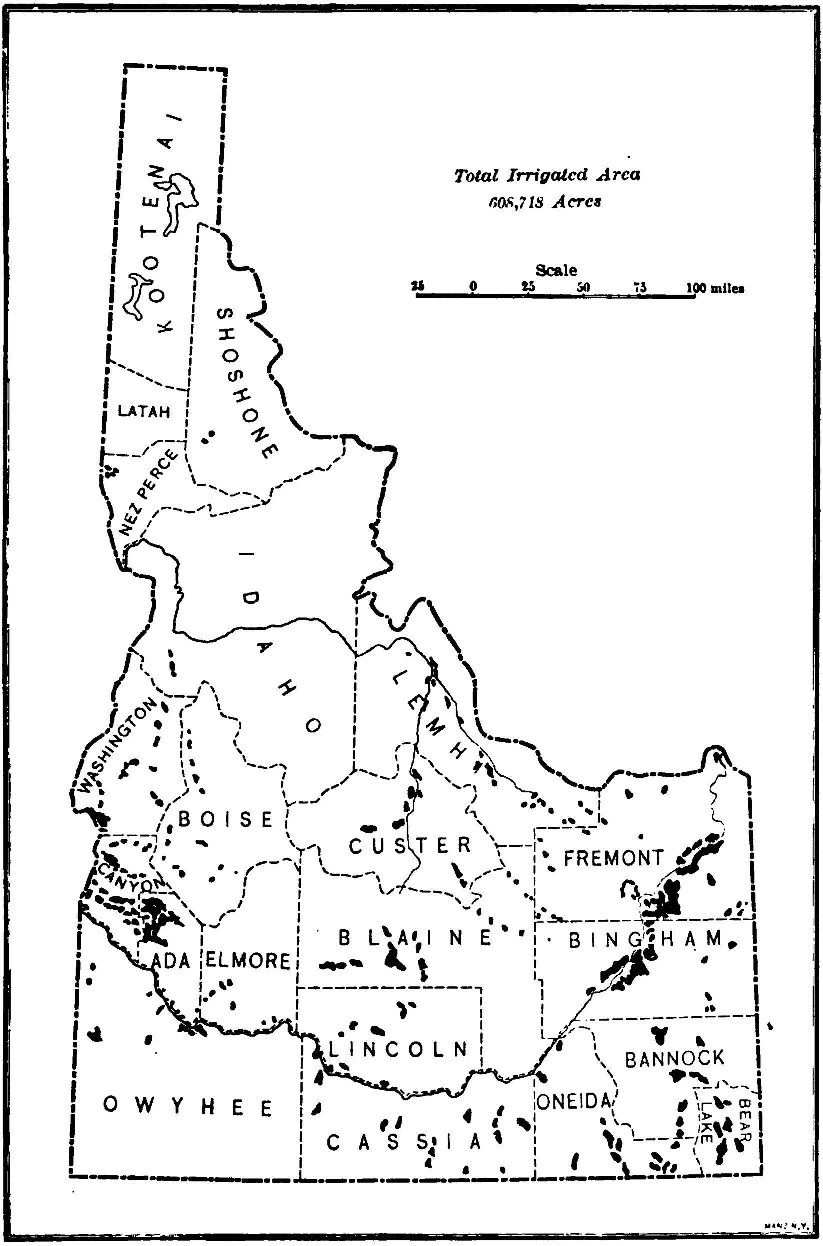

FIG. 22.—Map of irrigated areas in Idaho.

irrigated lands, as shown by the map (fig. 22), are mostly in the southern counties. The largest area is near the headwaters of Snake

River, on the eastern side of the State, and is devoted mainly to forage crops. On the western side of the State the irrigated areas are smaller, but, the altitude being lower, the value of the crops per acre is larger. The following table shows the area of vacant public land on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office will be found on page 19.

Unappropriated, reserved, and appropriated areas in Idaho on June 30, 1901.

County.	Area unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Ada	604,892	639	147,749	753,280
Bannock	867,466	750,000	381,254	1,998,720
Bear Lake	407,479	....	209,481	616,960
Bingham	1,130,001	50,640	1,580,319	2,760,960
Blaine	3,759,756	55,680	222,324	4,037,760
Boise	2,462,293	....	227,627	2,689,920
Canyon	540,253	....	309,027	849,280
Cassia	2,355,809	26,263	504,968	2,887,040
Custer	2,918,656	11,840	58,304	2,988,800
Elmore	1,382,526	10,620	162,694	1,555,840
Fremont	2,553,279	1,280	1,378,241	3,932,800
Idaho	6,704,367	12,000	370,993	7,087,360
Kootenai	2,361,212	231,429	988,159	3,580,800
Latah	92,665	....	620,295	712,960
Lemhi	2,668,667	82,960	99,573	2,851,200
Lincoln	1,822,652	45,680	224,468	2,092,800
Nez Perce	284,211	139,000	486,229	909,440
Oneida	1,131,648	250,000	343,152	1,724,800
Owyhee	4,801,318	9,920	249,242	5,060,480
Shoshone	2,673,027	69,360	250,893	2,993,280
Washington	1,605,159	....	255,961	1,861,120
Total	43,127,336	1,747,311	9,070,953	53,945,600

The opportunities for the reclamation of arid lands are confined mainly to the southern part of the State, since, as above stated, the valley lands of the northern end are relatively limited and humid. The broad lava-covered plains of the south are for the most part still owned by the General Government. Water has been taken out of the tributary streams wherever it could be diverted at moderate expense. The largest development of unutilized lands is that made possible by the complete control and diversion of the waters of Snake River. The matter has been studied with great care by Mr. D. W. Ross, who, through his position as State engineer of Idaho, has given particular attention to various problems.

SNAKE RIVER DIVERSION.[a]

The following statements are taken from a preliminary report by Mr. Ross upon the conditions existing in Snake River Valley. He calls attention to the fact that the rapid development of the agricultural resources of the upper Snake River Valley during the last three years has aroused more than ordinary interest in projects for the reclamation of other large bodies of desert lands in that vicinity. Although this development may be said to have just begun, the diversion of the entire flow of the river during the month of August, 1901, surprised the people of the district and showed how necessary it is that the public should be in possession of more facts in relation to the demands which are likely to be made upon this source of water supply before many years, and in regard to the storage facilities which exist for regulating the flow of Snake River, so that all the land depending upon it may be reclaimed.

The lands classified as "irrigable" in this discussion are those lying below the level of canals already constructed or partly constructed, or below the line of proposed canals whose construction is known as feasible.

UPPER SNAKE RIVER VALLEY.

What is known as the "Upper Snake River Valley" is the country lying between American Falls and the headwaters of the river. The irrigable portion of this valley is about 135 miles long, and averages nearly 9 miles in width, comprising, all told, about 700,000 acres. Of this tract about 215,000 acres are now irrigated; about 490,000 acres lie below the level of canals already constructed or partly constructed; about 121,000 acres are within the boundary of the Fort Hall Indian Reservation, while the remainder, 90,000 acres, lies below the level of a proposed canal system on the west side of the river near the lower end of the valley. There are 30,000 acres of irrigable lands on the upper tributaries, of which 15,000 acres are irrigated.

The fall of the river through the upper portion of the valley averages nearly 6 feet per mile. The high-line canals on the east side of the river follow the foothills, which rise rapidly into high mountains. The contour of the west side is comparatively level, great plains stretching out from 20 to 75 miles from the river, constituting what is commonly known as the "Great Snake River Plains."

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[a] From report of D. W. Ross, State engineer of Idaho.

The monotony of the seemingly level plains is broken by several broad and low volcanic cones and by three prominent peaks known in

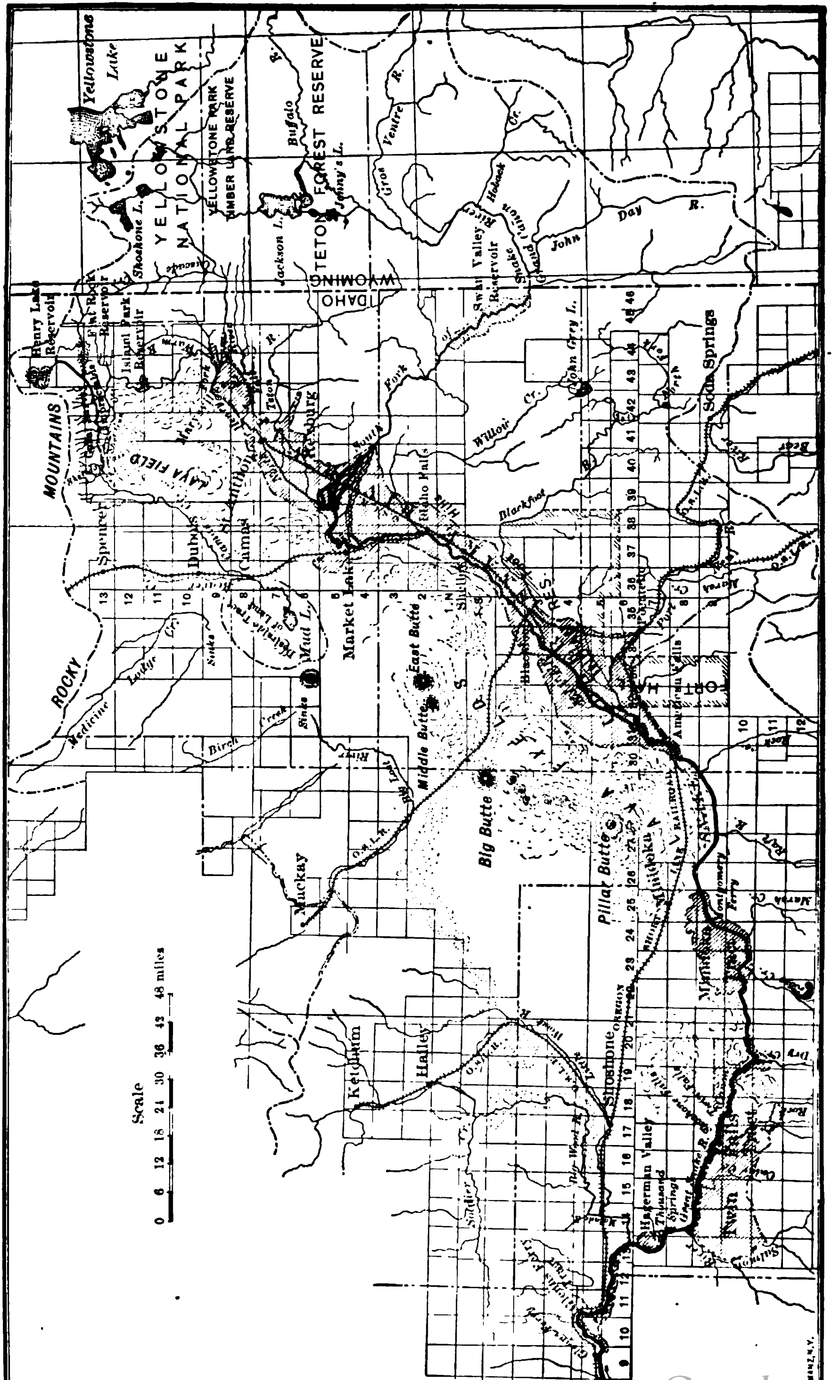

FIG. 23.—Map of irrigable lands of the Snake River Valley.

their order from northeast to southwest as East, Middle, and Big buttes, respectively. East and Big buttes are old volcanoes, composed of light-colored rock, which differs from the black lava of more recent date which completely surrounds them, and covers a territory of more than 10,000 square miles. Portions of this vast lava field have become smoothed over and covered by alluvial material laid down by Snake River and its tributaries and by deposits of atmospheric dust and fragments ejected by volcanoes. The bare lava still appears on the surface, however, throughout a large part of this area.

The irrigable portion of the upper valley is bounded on the west without a break by the lower edge of the lava field, which is from one-half mile to 8 miles distant from the river. Nearly all the land fit for cultivation lying between this field of lava and the river is covered by canals already constructed or projected. They are all forced to skirt the edge of the lava fields. This deposit is from 20 to 40 miles wide.

The following table shows the location and area of the irrigable lands of Upper Snake River and its principal tributaries, also the acreage now under cultivation.

Acreage and location of irrigable land in Upper Snake River Valley.

Location.	Stream.	Acres irrigable.	Acres irrigated.
Scattered tracts on upper branches of main tributaries of Snake River		30,000	15,000
East side of main valley:			
Marysville tract, between Fall River and Henry Fork.	Fall River	30,000	7,000
Wilford and Salem tract, between Fall and Teton rivers.	Henry Fork, Fall and Teton rivers.	20,000	13,000
Rexburg tract, between Teton River and South Fork of Snake River.	Teton River and South Fork of Snake.	105,000	45,000
Idaho Falls tract, between the South Fork and Blackfoot River.	South Fork and Snake River.	220,000	82,000
Reservation tract, between Blackfoot River and American Falls.	Snake River	120,000	2,000
West side of main valley:			
Egin Bench and Market Lake tracts.	Henry Fork	60,000	41,000
Lands under Great Western canal system.	Snake River	20,000	10,000
Lands below level of proposed American Falls canal system.	do	125,000	15,000
Total		730,000	230,000

All the works now constructed or in process of construction are in the upper valley. These works are all very simple in character. In no case have expensive diversion dams been necessary; none of the canals have made very deep cuts or are constructed through rock or other hard substance; neither do they pass over much, if any, side hill or steep, sloping ground. The land irrigated by these is in nearly every instance reached at a short distance from the point of diversion, the fall of the valley being decided. These conditions, together with almost entire absence of other engineering difficulties, have made canal building in this section a very easy task and have led to the construction of a large number of canals, nearly all built by the landowners themselves.

Most of the lands which are irrigated from Henry Fork lie on the west side of the river, nearly all of those on the east side being irrigated from Fall and Teton rivers. These lands lie about 10 miles above St. Anthony, the highest canal heading a short distance above the mouth of Fall River. This body of irrigable land lies between the lava fields and the river and reaches from the mouth of Fall River to Market Lake. It is from 1 to 4 miles wide and about 40 miles long and contains about 60,000 acres. The upper portion of this tract, about 40,000 acres, is known as "Egin bench" and is irrigated by the Last Chance, Egin, St. Anthony, and Independent canals. The lower portion is under the Butte and Market Lake canal.

The lands susceptible of irrigation from Fall River lie between that stream and Henry Fork, in what is known as the Marysville district, and below this on the east side of Henry Fork. The first body contains an area of about 30,000 acres and is covered by the Marysville canal. The second body contains an area of about 20,000 acres, most of which is under the Fall River canal. About 12,000 acres in the vicinity of Wilford, Salem, and Rexburg are covered by canals diverting water from Teton River. The large body of land lying between the North and South forks, about 105,000 acres, is irrigated from both of these streams, also from Henry Fork. The greater portion of these lands is situated on the first bottom near the junction of the North and South forks of the river. The irrigation works in this section are of the most simple character imaginable. These rivers flow through a broad, level valley with a slope of from 4 to 6 feet per mile. The Teton and South Fork have numerous channels which are easily dammed. The water is carried out onto the surface at but little expense.

The largest canals which conduct water to lands on the east side of the valley between the South Fork and Blackfoot River divert the water from the South Fork. These are the Eagle Rock and Willow Creek and the Idaho canal system. The other principal canals are the Idaho Falls, City, Snake River Valley, Cedar Point, Blackfoot Irrigation Company, and Corbet Slough canals.

The irrigable land on the west side between the lower end of the Market Lake tract and the town of Blackfoot lies under the Great Western canal system, now the property of the New Sweden irrigation district. The Great Western and the Porter canals are the principal ditches of this system. The Peoples canal diverts its water from the main river about 8 miles above the town of Blackfoot and near the lower end of the Great Western canal. This canal is about 25 miles long and covers about 20,000 acres. A portion of this land is also covered by the Lava Side ditch.

The large body of irrigable land now belonging to the Fort Hall Indian Reservation, about 121,000 acres, lies below the level of the reservation canal. This is a small canal constructed for the use of the Indians, under the supervision of the Commissioner of Indian Affairs. It takes its water from Snake River near the town of Shelley. Its course is almost south for 11 miles, where it discharges the water into the channel of Blackfoot River. After flowing in this channel for about 10 miles, it is led out onto the plains along the foothills extending in a southerly direction, the present ending being at Ross Fork. It has a capacity of 300 second-feet in its upper portion and 100 second-feet at its lower terminus. If extended on its present grade plane, it would cover most, if not all, of the town site of Pocatello. In all probability, however, it will be found much more economical to construct the main canal for the irrigation of this great body of land on a slightly lower level than the present one.

PRINCIPAL WORKS PROJECTED IN UPPER VALLEY.

The large body of bench land on the north side of the river, between Blackfoot and American Falls, is covered by the proposed American Falls canal system. This canal will be about 65 miles long, 60 feet wide on the bottom, and will have a capacity of 1,300 second-feet. It will cover about 90,000 acres, 75,000 of which is first-class land in every respect. About 57,000 acres of these lands have been segregated from the public domain under the provisions of the Carey Act. This canal follows around the edge of the lava fields and terminates near American Falls. At this point it is only about 3 miles back from the river. A narrow strip of land below the level of the canal extends down the river for several miles. It is very broken in places, however, by ridges of lava which would make canal construction very expensive. The estimated cost of these works is placed at $350,000.

While no definite plans have ever yet been made for the reclamation of the great body of lands of the Fort Hall Indian Reservation, there is no doubt that sooner or later their irrigation will be provided for. No serious engineering features will have to be overcome in this work. The main canal for this purpose will probably divert the river a few miles above the town of Blackfoot. It would probably be necessary to utilize a portion of the channel of Blackfoot River, from which it would divert near the head of the present reservation canal. The main canal of this system would perhaps parallel the present canal, but on a level from 15 to 20 feet lower. It would be about 50 miles long and would cover nearly 100,000 acres of land. It should have for this purpose a capacity of 1 second-foot for each 70 acres of land, or 1,430 second-feet, which would require a bottom width of about 65 feet.

A rather large body of land lying east of Rexburg, between Teton River and the South Fork of the Snake, will probably be reclaimed by a canal taken from Fall River. It is doubtful if any other large canals will ever be built in the upper valley, since practically all of the land susceptible of reclamation can be covered and supplied with water by extending and enlarging the present systems.

The following tables show that the principal canals now in operation in the upper valley have a total length of 780 miles, a combined capacity of 8,157 cubic feet per second, and cover about 465,000 acres of land, 230,000 acres of which are irrigated. The two large proposed systems at the lower end of the valley will cover 190,000 acres, making a total of 655,000 of the 730,000 acres of irrigable lands of the valley. This leaves 75,000 acres which are not covered by any of the canals reported, but which can be reached by extensions of the present systems. Of the lands lying below the present canals, 235,000 acres are uncultivated. Nearly all of this land lies below the canals already constructed and will be reclaimed by enlarging and extending these works.

Principal irrigation works of the Upper Snake River Valley.

Canals.	Length.	Width.	Flow.	Number of acres under ditch.	Number of acres irrigated.
HENRY FORK.	*Miles.*	*Feet.*	*Sec.-feet.*		
St. Anthony union canal	40	26	400	22,000	20,000
Independent Canal Co., Limited	22	35	300	12,000	5,000
Butte and Market Lake canal	16	40	280	19,000	4,000
Egin canal	13	40	300	12,000	9,000
Twin Grove Canal and Irrigation Co	5	30	160	10,000	1,500
Dewey canal	9	12	70	1,800	500
FALL RIVER.					
Marysville canal	30	30	80	25,000	5,000
Fall River Irrigation Co., Limited	31.5	35	357	6,000	5,000
Cur and Brown canal	2	19	48	1,280	1,140
Farmers' Own Ditch Co., Limited	10	15	30	5,000	500
Chester canal	1	25	286.5	7,400	1,800

Principal irrigation works of the Upper Snake River Valley—Continued.

Canals.	Length.	Width.	Flow.	Number of acres under ditch.	Number of acres irrigated.
FALL RIVER—continued.	*Miles.*	*Feet.*	*Sec.-feet.*		
Joseph Bell ditch	1.25	7	10	160	100
McBee ditch	.75	12	20	800	300
Cantwell, Silkey, and Drake ditch	3	12	25	500	300
TETON RIVER.					
Salem union canal	11	24	100	4,000	1,500
Teton Irrigation and Manufacturing Co	7	22	60	2,265	2,265
Wilford Irrigation and Manufacturing Co	4.75	24	70	3,900	3,500
Good Luck canal	1.25	14	200	1,105	1,105
North Salem canal	2	13	40	1,000	600
Pioneer ditch	2.5	12	24	460	460
SOUTH FORK.					
Burgess canal	14	25	400	15,000	15,000
Long Island irrigating canal	3	25	300	20,000	16,000
Liberty Park Irrigation Co	4.5	20	100	4,000	1,500
Parks and Lewisville Irrigation Co.	12	21	200	10,000	4,500
Rigby Canal or Irrigation Co	5.5	18	140	7,000	3,400
Island Irrigation Canal Co	5	20	50	3,000	1,200
La Belle canal	4.75	24	18	1,250	900
Lyman Irrigation Co., Limited	6.5	12	20	1,500	1,235
Square Top Grove Canal Co., Limited	2.5	12	20	1,500	1,500
North Rigby irrigating canal	4	10	30	600	400
Poverty Flat Irrigation Co	20	60	200	8,500	3,000
Idaho Falls canal	26	40	400	30,000	20,000
Eagle Rock and Willow Creek Water Co	100	50	400	50,000	15,000
Farmer's Friend	5	28	50	7,500	4,500
Harrison canal	7	24	200	10,000	7,000
SNAKE RIVER.					
Great Western canal	70	45	160	12,000	7,000
Idaho canal	40	25	200	25,000	12,000
City canal of Idaho Falls	20.5	68	400	10,000	....
Peoples canal	25	30	240	20,000	6,000
Cedar Point canal	7	23	100	4,000	4,000
Snake River Valley canal	5	38	200	10,000	6,000
Reservation canal	33	25	300	15,000	2,000
Lava Side Ditch Co., Limited	10	27	121	6,000	3,000

Principal irrigation works of the Upper Snake River Valley—Continued.

Canals.	Length.	Width.	Flow.	Number of acres under ditch.	Number of acres irrigated.
SNAKE RIVER—continued.	*Miles.*	*Feet.*	*Sec.-feet.*		
Danskin ditch No. 1	12	35	200	10,000	4,200
Blackfoot Irrigation Co	5	50	200	17,500	5,000
Corbett Slough Ditch Co	5	16	120	4,000	2,500
Woodville canal	5	16	60	2,500	1,600
Danskin ditch No. 2	6	20	75	3,000	2,000
SMALL UPPER TRIBUTARIES.					
Rows ditch	1.5	15	25	2,000	1,200
Trude ditch	3	6	10	400	300
Rea ditch	1	7	8	160	100
Other small ditches	100	....	350	17,440	13,400
Total	779.75	....	8,157	464,920	230,005

Irrigation works projected in the Upper Snake River Valley.

Canal.	Stream.	Length.	Width.	Capacity.	Area covered.
		Miles.	*Feet.*	*Sec.-feet.*	*Acres.*
American Falls	Snake River	65	60	1,300	90,000
Reservation	....do	50	65	1,430	100,000
Total		115	....	2,730	190,000

LOWER SNAKE RIVER VALLEY.

Snake River, from American Falls westward to its mouth, is from 50 to 1,000 feet below the surface of the great valley through which it flows. The conditions surrounding irrigation in this portion of the Snake River Valley are very different from those just described. While the country generally is smooth and unbroken, the valley is underlain by a great floor of lava as far west as Caldwell. The outcroppings of this lava are less frequent than in the upper valley. There are practically no branches affording a perennial flow, nor tributary valleys of any account, on the north side of the river from Henry Fork to the west line of the State. Only two streams of any consequence, Salmon and Bruneau rivers, join it on the south between American Falls and Oregon. These streams emerge from narrow canyons cut deep into the lava formation of the plains of the northern portion of Cassia and Owyhee counties. The soil is nowhere gravelly, like that of the upper valley proper, but is a fine clayey or sandy loam, covered by a dense growth of sagebrush. The lava ridges, where they do appear, are more nearly covered by earth and do not present the bare and ragged appearance of the great lava fields which border the northwest edge of the upper valley.

The following table shows the location and extent of the irrigable tracts west of American Falls:

Irrigable lands of Snake River Valley west of American Falls.

Lands.	Source of supply.	Acres irrigable.	Acres irrigated.
Minidoka tract	Snake River	85,000	
Twin Falls tract	do	240,000	
Hagerman Valley	Springs	8,000	4,000
Glenns Ferry tract	Malade River	12,000	
Grandview tract	Bruneau River	10,000	2,000
Succor Creek tract	Snake River	15,000	
Total		370,000	6,000

Minidoka tract.—About 85,000 acres of land can be irrigated from a point near the head of the Minidoka Rapids. A dam will be required which will raise the level of the river about 48 feet. A good site exists. About 75,000 acres of these lands lie on the north side of Snake River and about 10,000 acres on the south side. The canal on the north side will be about 35 miles long, 50 feet wide on the bottom, and have a capacity of 1,060 second-feet. The south-side canal will be 8 miles long, 18 feet wide on the bottom, and have a capacity of 170 second-feet. The cost of constructing this system is estimated at $730,000, which provides for storage for 60,000 acre-feet, enough to supplement the natural flow of the river, providing a full supply during the month of August. This project has not yet passed beyond the stage of plans and surveys.

Twin Falls tract.—Plans for the reclamation of the large body of land in the vicinity of Shoshone Falls, known as the "Twin Falls" irrigation project, have advanced as far as the making of careful surveys of the dam and canal system and estimates of cost and the segregation of about 244,000 acres of lands from the public domain under the provisions of the Carey Act.

The canals, as located, embrace an area of about 270,000 acres. Of the irrigable lands of this area—some 240,000 acres—221,000 are first class in every respect, the remaining 20,000 acres being of second and third grade. About 212,000 acres of these lands lie on the south side of the river and can be irrigated by a canal 69 miles in length.

It should have a bottom width of 80 feet and a depth of 10 feet for the first 20 miles, gradually narrowing to a width of 20 feet and a depth of 5 feet at the lower end. A canal on the north side can irrigate about 28,000 acres. It should be about 19 miles long, have a bottom width at the head of 26 feet, and carry water to a depth of 6 feet. The dam should be about 700 feet in length, arching upstream. It can be constructed of loose rock, with an upstream face of rubble concrete. It will raise the water level about 49 feet and can be carried well above the flood level of the backwater. The river can be discharged over a wasteway about 600 feet long, located at the south end of the dam. Provision can be made in the wasteway for controlling the level of the backwater at low stages of the river.

The south-side canal, as planned, will have a capacity of 3,000 second-feet, while the capacity of the one on the north side will be 400 second-feet. The south-side canal will thus have a capacity of 1 second-foot for each 71 acres of irrigable land, or for each 57 acres of land actually cultivated, while the capacity of the north-side canal will be 1 second-foot for each 70 and 56 acres of irrigable and irrigated land, respectively. The estimated cost of the works is $1,520,000, or less than $7 per acre.

Only four considerable bodies of land bordering on Snake River can be irrigated between Salmon River and Oregon, and but one of these will obtain its water from the main stream source. These are as follows:

Hagerman Valley.—The canyon of the Snake ends near the mouth of Salmon River, the great lava wall on the south entirely disappearing, giving way to clay and gravel bluffs, while on the north the wall of the canyon falls back from 1 to 3 miles from the river, leaving a little body of about 8,000 acres between. This is Hagerman Valley, which is about 8 miles long, from 1 to 3 miles wide, and from 25 to 100 feet above the river. It is irrigated from great springs which break out from the north canyon wall at many places, at an elevation of from 50 to 180 feet above the river. This little valley is from 200 to 400 feet below the surrounding plains.

Glenns Ferry tract.—This body of land lies on the south side of the river, opposite Glenns Ferry, beginning near the mouth of the Malade and extending down the Snake for about 22 miles. It is a narrow strip of land, situated at an elevation of from 30 to 200 feet above the Snake, too high for irrigation from that source. Water for its irrigation will therefore be obtained from Malade River.

Grandview tract.—Another strip of land similarly situated begins below the mouth of the Bruneau and extends down the south side of Snake River to Grandview, a distance of about 18 miles. This tract contains an area of about 10,000 acres, water being obtained for its irrigation from the Bruneau by means of the Owyhee Land and Irrigation Company's canal.

Succor Creek tract.—A small body of land, about 15,000 acres, near the mouth of Succor Creek, situated on the south side of Snake River near the Idaho-Oregon State line, can be irrigated by the waters of this stream. The point of diversion of the canal which would cover these lands is above the Swan Falls dam. The canal would be about 30 miles long. No estimates of its cost have ever been made, but it would be expensive.

These four small tracts, comprising in all about 45,000 acres, constitute practically all of the land susceptible of reclamation by means of surface water in the Snake River Valley between Salmon River and Oregon, with the exception of a few scattered ranches along the first bottom of the river and on the north side in the vicinity of Glenns Ferry.

The following table shows that the proposed canals which will divert their water from Snake River in the lower valley will have a total length of 161 miles and a capacity of 4,880 second-feet, and will cover 340,000 acres. The Succor Creek canal will divert at a point on the river where the question of the sufficiency of the water supply will never arise.

The other works, which are the only ones that need be considered at this time, will have a total capacity of 4,630 second-feet and will divert their supply at points on Snake River where the mean August flow in 1901 was only 2,115 second-feet.

Proposed canal systems of the Lower Snake River Valley.

Canal.	Stream.	Length.	Bottom width.	Capacity.	Area covered.
		Miles.	*Feet.*	*Sec.-ft.*	*Acres.*
Minidoka system	North side Snake River.	35	50	1,060	75,000
Do	South side Snake River.	8	18	170	10,000
Twin Falls system	North side Snake River.	19	26	365	28,000
Do	South side Snake River.	69	80	2,465	212,000
Succor Creek system	Snake River	30	20	250	15,000
Total from Snake River.		161		4,880	340,000
Hagerman Valley canals.	Springs	40		80	8,000
Glenns Ferry canal	Malade River	15	16	250	12,000
Grandview canal	Bruneau River	18	20	250	10,000
Grand total		234		5,460	370,000

CONDITIONS WHICH LIMIT THE AREA OF IRRIGABLE LAND.

In the Upper Snake River Valley the irrigable lands are bounded on the west by the lava fields and on the east by steep, broken foothills. A high ridge which crosses the river below American Falls fixes the lower limits of the upper valley. From the American Falls westward to the head of the great canyon the river has slight fall. A fine body of land lies south of the river between these points. The lateral slope of the land is so steep, however, that but little of it could ever be reclaimed even if it were practicable to extend the high lines of the upper valley. As before stated, there are only two points along this course of the river at which water can be diverted onto the high bench lands. High dams will have to be constructed at both of these places. These dams can be carried to only a reasonable height, which effectually places a limit upon the area of land that can ever be reclaimed in this portion of the valley.

The construction of the proposed canals on the north side of the river in the upper valley will be comparatively easy, but in order to reach any large amount of land beyond their present location, say east of Malade River, they would have to be carried over miles of lava fields, at an expense which would probably not be warranted for many years to come. A canal covering any of the high table-lands west of Malade River would have to be diverted at a point at least as far east as Minidoka Rapids. It would have to be constructed through a lava formation upward of a hundred miles, following a route over which railroad construction has been deemed impracticable. Any plan, therefore, for the reclamation of the lands of the high plateau in that vicinity by the waters of Snake River would be visionary.

The water used for the irrigation of these lands is obtained from Snake River and its main tributaries. The lands under consideration are practically all in the Snake River Valley proper, and while much of the upper country is irrigated from the main tributaries of this stream, as Henry Fork, Fall and Teton rivers, and the South Fork, the lands so irrigated form a part of the unbroken body of irrigable land reaching from the American Falls to Marysville, a distance of more than 135 miles. These lands are much the same in character, the supply of water obtained from the various sources fluctuating about the same, while practically the same conditions are met with on the different streams, even to the manner of constructing canals and ditches.

For these reasons, and owing to the fact that but meager information is at hand in relation to the daily discharge of these tributaries, the consideration of the water supply for all the irrigable lands of the valley will necessarily be based upon observations and records of the flow of the river at points lower down. A record was made of the discharge of Henry Fork and of Fall and Teton rivers during the years 1889 to 1892; also of the flow of the main river at Idaho Falls during the same period. In 1895 a gaging station was established at Montgomery Ferry, about 45 miles below American Falls, below all irrigation in the upper valley, where daily measurements have been made ever since, with the exception of the year 1900. Some years these measurements extended throughout the entire year; some years observations were not made during the winter months, but as the winter flow of this stream is very uniform the estimates of the yearly discharge for each year of this period is thought to be safe. The following table shows the yearly discharge, in acre-feet, of Snake River from 1899 to 1901; also the mean flow, in second-feet, during each month of the irrigation season, from measurements at Idaho Falls and Montgomery Ferry:

Mean discharge of Snake River at Idaho Falls and Montgomery Ferry during the irrigating seasons 1889–1901.

Place.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
IDAHO FALLS.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Acre-feet.*
1889			5,184	2,596	2,300	2,286	
1890	35,606	34,870	19,970	7,875	4,934	4,552	7,736,000
1892	18,187	41,357	24,069	6,463	4,312	4,156	7,279,000
MONTGOMERY FERRY.							
1895				4,773	4,514	4,615	
1896	9,357	39,551	13,341	5,450	4,972	4,975	5,800,000
1897	32,863	30,399	10,704	5,223	4,982		7,300,000
1898	17,658	20,936	9,142	4,498	4,383	4,818	5,900,000
1899	12,187	29,142	26,270	8,477	5,813	5,598	6,600,000
1900[a]				2,810			
1901	23,020	15,700	4,511	2,115	2,568		5,000,000

[a] Discharge August 20–24, 2,150 second-feet; discharge August 25, 2,810 second-feet. These were the only measurments made during 1900.

As before stated, practically all of the water of the river was diverted for irrigation during the first week of August, 1901, at a point a few miles below Blackfoot. At American Falls, 20 miles lower down, the discharge during the same week was 2,100 second-feet. This gain represents the seepage flow and the discharge of springs on the north side of the river and near the mouth of Spring and Ross Fork creeks, which reach the river a short distance above the falls. The measurements at Montgomery Ferry, while indicating fairly accurately the available supply during the season of high water, do not indicate the flow of the river through the upper valley during the month of August. They do show, however, the supply available for the irrigable lands below American Falls during the latter part of the irrigating season. The total available supply would really be the volume measured at Montgomery Ferry plus the amount diverted and used for irrigation in the upper valley. This amount has, of course, varied from year to year, having increased probably from 200,000 acre-feet in 1896 to about 650,000 acre-feet in 1901. These amounts are based upon the assumption that an average of 3 acre-feet would actually be used in irrigation, absorbed by vegetation, and lost by evaporation, while perhaps 40 per cent of the water diverted by the canals would return to the river through surface drainage and seepage. Besides this there should be added about 630,000 acre-feet to the supply of 1890 and 1892, the discharge of the springs above American Falls and below the point of measurement of those years. This amount would be available for use on lands lower down the valley.

On this basis the amounts showing the total available supply indicated in the table referred to should be increased somewhat and would be about as follows:

Total available water supply in Snake River, 1890–1901.

Year.	Acre-feet.	Year.	Acre-feet.
1890	8,366,000	1898	6,250,000
1892	7,910,000	1899	7,050,000
1896	6,000,000	1901	5,650,000
1897	7,575,000		

The above table shows that the total available water supply each year varies from 6,000,000 to 8,000,000 acre-feet, the average for the seven years being about 6,930,000 acre-feet. This amount, if all held under perfect control by storage works, would be the total supply from every source for irrigation in Snake River Valley.

Of the above amount about 14 per cent, or 970,000 acre-feet, comes from the Henry Fork drainage; about 12 per cent, or 830,000 acre-feet, from the Fall River drainage; about 9 per cent, or 630,000 acre-feet, from the Teton River drainage; while 56 per cent, or 3,880,000 acre-feet, is supplied by the South Fork. The remaining 9 per cent, or 630,000 acre-feet, is supplied by springs and seepage above American Falls, and will be available for use on the lower tracts. Only the summer flow from the latter source is counted. The winter flow could not be stored, and would therefore run to waste.

The flow of the river as measured at Montgomery Ferry includes the flood discharge of Blackfoot and Portneuf rivers. The summer flow of these streams is very small and is practically all used for irrigation in the upper valleys, and would therefore be ignored as a factor in this case.

IRRIGATION.

While the Hagerman Valley, Glenns Ferry, and Grandview tracts are in Snake River Valley proper, they will not obtain their water from Snake River, and will therefore not be considered in this discussion. Neither will the Succor Creek tract, as the sufficiency of the water supply will never become a question of great concern in relation thereto. We will therefore consider the irrigation of only those lands whose water supply will be diverted either directly from Snake River or from the main tributaries flowing through its upper valley, about 1,055,000 acres in all.

Like the pioneer irrigators of most of the large western valleys, the settler of the Upper Snake River Valley has always been a firm believer in the use of a generous supply of water in irrigation. The basis of his relation to his company is usually the right to receive continuously a certain volume of water from the canal, usually at the rate of 1 inch, or the one-fiftieth part of a second-foot, to each acre of land. The farmer, having helped construct the canal, can see no good reason why, after having gone to the expense of giving it a generous capacity, he should not use plenty of water, and, having all the facilities for diverting plenty, why he has not really established an unquestionable right to use all he can divert from the river.

In suits for the adjudication of water rights and for the allotment of the waters of the streams in the southeastern portion of the State there has been but little conflicting testimony regarding the quantity of water necessary for the proper irrigation of crops, the irrigators, as a rule, making very generous claims, and there being no limit established by law to the amount per acre to which he is entitled, the courts have usually made decrees in accordance with the evidence submitted, with the result that, no matter whether the lawyer or client happened to know anything about the quantity of water which had been used or which would be needed, the claim allowed has usually been at the rate of "an inch to the acre." This has almost become a custom, and without any very close inquiry into the physicial conditions which surround each case the courts have practically adopted this convenient allowance, and it has proved an easy solution of many of the vexed questions which occur in irrigation litigation.

With a supply of water flowing through the valley that to the farmers seemed inexhaustible, the gravelly character of a large portion of the lands of this district, and the example of generous claims allowed by the courts to the waters of neighboring streams, it is not surprising that the irrigators of this section have not given their water supply a very high duty.

At the present time about one half the irrigated area is devoted to the growing of hay, the other half being cultivated mostly to grain, with a large acreage of potatoes in some sections of the valley. Two cuttings of hay are made—the first in the early part of July and the last during the second or third week of August. Grain is harvested from the middle of August to the middle of September. The proportion of meadow will undoubtedly increase as the stock and dairy industries become more thoroughly established.

In the lower valley the proportion of alfalfa will probably be greater than in the upper. Here three cuttings can be made—the first during the latter part of June, the second about the 1st of August, and the third in September. Grain is harvested in this section about the 1st of August, its last irrigation occurring about the middle of July.

No measurements have been made of the water used in irrigation in Snake River Valley, but careful observations of the practices of the irrigators in the southwestern valleys of the State render possible a pretty close estimate of the amount used in that place. The amount of water used in Boise and Payette valleys varies from 2.5 to 6 feet in depth during the irrigating season, or from 2.5 to 6 acre-feet for each acre irrigated, depending somewhat upon the quality of the land and the kind of crops, but more particularly upon the system employed in its distribution to the irrigator. During the season of 1901 daily measurements were made of the quantity of water delivered to each irrigator under the Boise and Nampa canal system in Boise Valley, which showed the amount per acre to vary from 2.5 to 6 acre-feet, the average over 22,500 acres being almost exactly 5 acre-feet. About 75 per cent of this area is meadow, 15 per cent grain, the remainder orchard, garden, etc. The amount used on grain varied from 1.5 to 3 acre-feet and about the same for orchards. A large number of the users made no effort to economize. In such cases 6 acre-feet were used in some instances. Where an effort was made to save water the amount varied from 2.5 to 4 acre-feet.

The lands throughout the greater portion of upper Snake River Valley, owing to their gravelly nature, require more water for their irrigation than those referred to—at least, more water is applied. A very large percentage of it undoubtedly returns to the river by seepage and surface drainage. We should be very safe, therefore, in estimating that the canals now in use divert during the irrigating season at least an average of 5 acre-feet per acre for all the lands cultivated.

This estimate would apply to practically all the lands now under cultivation. While the lands require a large amount of water, it should be quite evident to any observant person that a large portion of the amount diverted is wasted and could be saved by leveling up the land, providing better drainage, and adopting better methods of irrigation.

About one-half of the irrigable lands of the valley are similar in character to those now under cultivation, but the remainder, or about

500,000 acres, are high bench lands and will not require so much water. The canals which will irrigate these bench lands will have a capacity of from one eighty-fifth to one-sixtieth of a second-foot for each acre of land to be irrigated. This would deliver from 3.5 to 5 acre-feet per acre during an irrigating period of about one hundred and fifty days. The amount which would actually be diverted from the river during each irrigation season would probably average about 4 acre-feet per acre over all the higher bench lands and about 4.85 acre-feet—which would be at the rate of 1 inch per acre during 80 per cent of the irrigating period, or one hundred and twenty-two and five-tenths days—over all the remaining lands, or an average of 4.43 acre-feet over all the irrigable lands in question, viz, 1,055,000 acres. This would require 4,675,000 acre-feet of water, not allowing for any loss whatever in distribution.

The distribution of the supply used during the irrigating season under the Boise and Nampa canal during 1901 was as follows: April, 7 per cent; May, 17 per cent; June, 18 per cent; July, 20 per cent; August, 20 per cent; September, 14 per cent; October, 4 per cent.

Owing to the small percentage of grain grown under this system (about 15 per cent), the use of water during May, June, and July would be less than in Snake River Valley.

Irrigation does not usually begin in Upper Snake River Valley until after the 1st of May, and its use ceases about the latter part of September. Allowing, then, for the greater percentage of grain and for the difference in the length of the season, the percentage and quantity used each month during the irrigating period would be shown by the following table:

Distribution of water used in irrigation in Snake River Valley.

Month.	Per cent (total 100).	Quantity.	Daily flow required.
		Acre-feet.	*Second-feet.*
May	19	888,250	14,470
June	[a] 28	1,309,000	22,051
July	26	1,205,500	19,670
August	15	701,250	11,423
September	12	571,000	9,611

[a] Assuming that it would be necessary to divert 4 acre-feet for each acre of bench land irrigated, 1.12 acre-feet per acre would be required during the month of June. For 100 acres an average of 3.73 acre-feet, or 1.87 second-feet, should be delivered each day. This would be at the rate of 1 second-foot for each 53 acres of land actually irrigated. From this the capacity of the canal could be estimated.

If the above table is compared with the table showing the monthly discharge of the river, it will be easily understood why it will soon be necessary to regulate the discharge of Snake River by means of reservoirs.

The conditions in the upper valley are very favorable for a large seepage flow, which would be available for the irrigation of all the lower tracts. Owing to the fact, however, that the Twin Falls tract will all be irrigated from one point of diversion none of the seepage flow from its irrigation will be available for irrigation on any other tract where it will ever be needed. The seepage from the irrigation of 815,000 acres would be available as a further source of supply.

The only investigations of the seepage flow in this State are those in Boise Valley, the results of which are shown in the Annual Reports of the Geological Survey.[a] In this valley, with less than 25 per cent of the irrigable land under cultivation and that scattered over a wide area, the average seepage flow from 1898 to 1901 was 18 per cent of the maximum amount diverted by the canals during the month of June.

The conditions are much more favorable for a large seepage flow in Snake River Valley than in Boise Valley; but assuming that it would amount to only 15 per cent of the June flow of the canals, the average supply of water available for irrigation would be increased during the months of July, August, and September, the two latter being the low-water months of the irrigating period.

The following table of discharges is based upon the mean flow of the river as measured at Idaho Falls during 1889 and 1890 and at Montgomery Ferry from 1895 to 1901. To these measurements as recorded have been added the following: To the measurements made at Idaho Falls, 2,100 second-feet, the amount supplied by springs above American Falls; to the measurements made at Montgomery Ferry, the amount used for irrigation in the upper valley during the years of such measurement and, in addition, the probable amount of seepage (some 3,000 second-feet, resulting from the irrigation of 815,000 acres) which would return to the river and be available for use again. It also shows the amount which the canals would divert each month during the irrigation season for the irrigation of 1,055,000 acres of land.

The first part of the table shows the supply which would be available for the irrigation of this amount of land. The last part shows the volume of water which would be needed for that purpose. It should be remembered that these amounts include all losses from every source.

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[a] Twentieth Ann. Rept., Pt. IV, pp. 481–488; Water-Supply Paper No. 38, p. 358; Water-Supply Paper No. 51, p. 429; Water-Supply Paper No. 66, p. 129.

Available water supply and the amount needed each month for the irrigation of 1,055,000 acres in Snake River Valley, based upon the discharge of the river from 1889 to 1901.

Year.	May.	June.	July.	August.	September.
	Second-feet.	*Second-feet.*	*Second-feet.*	*Second-feet.*	*Second-feet.*
1889			10,284	7,696	7,400
1890	40,706	39,970	25,070	12,975	10,034
1892	23,287	46,457	29,169	11,563	9,412
1895				7,773	7,514
1896	12,977	43,494	17,188	8,939	8,376
1897	36,714	34,695	14,869	8,895	8,537
1898	21,741	25,585	13,624	8,353	8,090
1899	16,580	34,263	31,176	12,577	9,722
1901	28,032	21,874	10,264	6,540	6,881
Mean	25,720	35,191	18,955	9,490	8,441
Amount required for the irrigation of 1,055,000 acres	14,470	22,051	19,670	11,423	9,611
Surplus	11,250	13,140			
Amount to be supplied by storage			715	1,933	1,170

This estimate would indicate that the natural flow of the river, with the seepage added, would furnish a large surplus—more than 10,000 second-feet—during the months of May and June, which would furnish enough for the irrigation of this amount of land during the months of July, August, and September. During only three years since this stream has been measured—1890, 1892, and 1899—would there have been sufficient water in the river to irrigate that much land; and whenever the supply is as low as it was in 1901 the shortage would be very great; in fact, during low years only about one-half enough water flows in the river after the month of June for the irrigation of 1,055,000 acres.

The estimate shows that the average shortage during July, August, and September would be about 715, 1,933, and 1,170 second-feet, respectively, or a total of about 232,000 acre-feet; and whenever the flow is as low as it was during the year 1901, the shortage would amount to about 1,050,000 acre-feet. An examination of the table shows that the July flow during five of the eight seasons recorded was much less than the mean, and that the flow during the month of August has been greatly below the mean six times out of nine, the mean flow during the six years referred to being 8,033 second-feet, or 1,457 second-feet less than the average of the nine seasons recorded. If the years 1890, 1892, and 1899 are left out of the calculations, being years of late flood flow, the mean available supply during the months of July, August, and September would be 13,246, 8,033, and 7,800 second-feet, respectively. This would be less than the average amount required by about 478,000 acre-feet, 350,000 of which would be needed during the month of July.

The following diagram illustrates the proportion which would exist between the volume of water required each month and the available supply flowing in the river.

The line showing the "available supply for irrigation from all sources" is based upon the mean supply of the years 1889, 1895, 1896, 1897, 1898, and 1901, the years of normal flow. A shortage is shown during the months of July, August, and September, which it can readily be seen would be covered by the surplus flow during the months of May and June alone. An examination of the table referred to shows that during no season would the river furnish this supply from its flow alone except during seasons like 1899, and even then there would very likely be a shortage during the month of September.

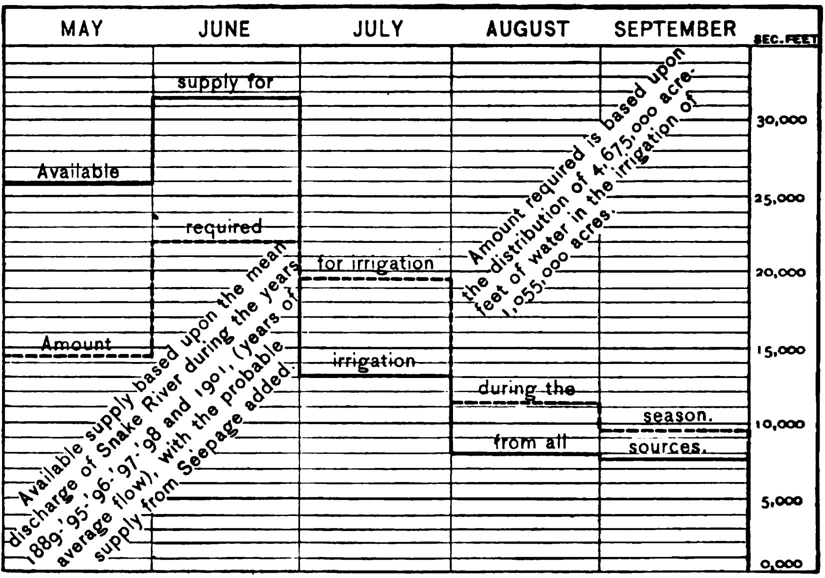

FIG. 24.—Diagram of available supply and amount required by irrigation, Snake River, Idaho.

That the above estimate of the use of water is not too liberal is evidenced by the fact that all the waters of the river were diverted during August, 1901, for the irrigation of about 215,000 acres in the upper valley. A supply reached the river lower down, however, as before explained, sufficient for the August and September irrigation of 240,000 acres. The flow of 1901 was then sufficient for the irrigation of at least 455,000 acres of the 1,055,000 acres of irrigable land which must depend upon this source of supply. Assuming that, through the practice of better methods, the supply of last season could be made to irrigate 50,000 acres more, there would still remain 550,000 acres to be supplied by storage. This would be the only supply for these lands during such years for a period of from forty to ninety days. Most of such lands would be seeded to meadow and would require during that part of the season from 40 to 50 per cent of the season's supply, or from 700,000 to 1,000,000 acre-feet. It would be necessary, then, to provide storage for about 1,000,000 acre-feet in order that all of these lands might be irrigated during the seasons of low water. From 500,000 to 700,000 acre-feet of this would be needed nearly every season, and all of it during years of extreme low water in the river.

INVESTIGATIONS OF IRRIGABLE LANDS.

The lands which have been described under the head of "irrigable" are all, as has been explained, below the level of existing canals or their extensions, or below the level of routes which have been surveyed and over which the construction of canals is known to be feasible. There are other large bodies of very desirable land, however, in Snake River Valley, but their reclamation is more or less problematical.

Many of these bodies are scattered throughout the great plains west of those designated "irrigable" on the map. Some are of small extent, containing from 1,000 to 10,000 acres, but their reclamation would be impracticable owing to their being above the source of supply. Many of them are below the level of the upper canals, but could not be reached because of intervening lava fields.

A large body of such land is situated on the northwestern boundary of the great lava field. This is the great tract of level land formed by the alluvial deposits of Big Lost and Little Lost rivers, and Birch, Blue, Medicine Lodge, Beaver, and Camas creeks, a great level plain in which these streams sink, lying between the foothills and the lava fields and extending many miles up their valleys. The main body of this land comprises an area of at least 250,000 acres, about one-half of which is near the lower end of the lateral valleys. As the discharge of these little streams is wholly inadequate for the reclamation of even the lands lying immediately tributary thereto, the only source of supply for the larger body is Snake River, and the discovery of a feasible route for a canal has been the serious problem in connection with its reclamation.

Investigations were accordingly begun in August, 1901, under the immediate supervision of the State engineer of Idaho, acting in cooperation with this Survey. A survey was made with a view of determining the feasibility of conducting the waters of Henry Fork through Sheridan Pass by means of a canal. The plan was then to utilize Dry Creek and a portion of Camas Creek, and at some suitable point on the latter the water was to be diverted into a distributing canal and conducted onto the lands in the vicinity of Mud Lake.

The initial point of such a line as this is the divide between Shotgun Creek, a tributary of Henry Fork, and Dry Creek, a branch of Camas Creek. This divide is a low pass at the head of Antelope and Sheridan valleys. The great lava fields begin abruptly on the south side of this pass and stretch away for 200 miles in a southwesterly direction, while the summit of the continental divide is only about 10 miles distant to the north. About a mile south of Sheridan Pass is a low ridge through the lava field, called "South Pass." This pass runs almost parallel to Sheridan Valley, separated from it by a low ridge of hills. It is about 48 feet lower than Sheridan Pass.

A line was started from South Pass and run in an easterly direction, but the country fell off so rapidly that by the time Sheridan Valley was reached it was well up on the sides of steep, rocky hills, where the cost of construction would be prohibitory. The line was abandoned as impracticable after running it a distance of 7 miles.

The following is a report of the survey from Sheridan Pass by Mr. D. G. Martin, the engineer in immediate charge of this investigation:

> The line through the North or Sheridan Pass was then begun and extended to station 265+80, which point is almost north of station 384+44, the end of the south line, and here the two lines were connected by a short line 2,474 feet long. The difference of elevation between the two lines is 32.7 feet, and the difference in elevation of the two passes is about 48 feet, the South Pass being the lower. The North Pass presents very few obstacles to construction except as to elevation. After connecting the two lines referred to the survey was extended on the elevation of the line through the North Pass in an easterly and northerly direction along the foot of the mountains to and a little beyond the crossing of Willow Creek, where the south end of a low lava plain was encountered. This lava plain was more or less broken and rough, and would necessitate a very great expense in construction. The line skirted the south edge of this plain to station 741+48 on the west bank of the canyon of the West Fork of Hotel Creek. The canyon has almost perpendicular rock sides at the point where the line intersected it, and is about 50 feet below the grade line. On the east bank of this canyon the line led into the timber and necessitated brushing the line almost all the way to the west edge of the Henry Lake bottoms. From the West Fork of Hotel Creek to station 1164+47, at the upper end of Coffeepot Rapids, where the line left the river, numerous small canyons were crossed, some of which were close to 100 feet in depth. At station 1164+47 a dip angle showed the line to be 139 feet above the water in the river. As we were then within about 6 miles of the head of Henry Fork proper, it was almost certain that the line would not intercept the river at all. From this point the line followed up the bank of a deep canyon which comes in from the northeast, while the river takes a southeast course. At the head of this canyon the line crossed the divide between Henry Fork proper and Henry Lake Basin about 15 feet above the crest of the divide. Observations at this point indicated so strongly that the line would not intercept the river or outlet from Henry Lake that it was decided to drop the topography notes from this point and run a level line only around to Henry Lake. From here the line did not follow the contour, but was kept out in the open country to avoid the timber, arriving at the outlet from the lake near the crossing of the old Park road. From here the line was run up the outlet to a point a little north of the south line of sec. 22, T. 15 N., R. 43 E., which seemed the most feasible point for a dam such as would be necessary to raise the water to an elevation high enough to

feed a canal constructed on the grade established. At this point I found that the grade line on which we had run was 40.5 feet above the water in the lake, necessitating the construction of a dam 50 feet in height, with no suitable location for such a structure. Other sites were examined, but no suitable location could be found. Had a suitable site been found the result would have been the same, as it would have been impossible to raise the water in the lake to an elevation sufficient to feed the canal. The investigation was at this point abandoned.

It will be seen from the foregoing report that in order to divert the waters of Lake Fork directly, without the aid of a dam, the cut through Sheridan Pass would be over 65 feet and more than 6 miles long, while through South Pass the cut would be more than 15 feet deep and from 2 to 4 miles in length, the greater portion being in solid rock. Add to these discouraging features the fact that the water supply available would be inadequate for the purpose, and it will be understood why the project was declared impracticable. In order to have been feasible from the standpoint of water supply, the line should have intersected Henry Fork below the great springs, its main source of supply. To do this the canal would have to be from 25 to 30 feet lower than the line surveyed, which would make the cuts through Sheridan and South passes about 90 and 45 feet, respectively. Had the location of a canal line from such a point proved feasible nearly the entire flow of Henry Lake would have been required, some 350 second-feet, while storage works on this stream and tributaries lower down would then be necessary to supply the lands around St. Anthony.

Much speculation regarding the construction of a canal over this route has been indulged in by the people of the vicinity for many years past, it being generally believed that the plan is entirely feasible. While the result of the investigation was disappointing to many, the problems in connection with the development of the lands of Snake River Valley proper have, by reason of the elimination of this plan, been simplified.

The lands in the vicinity of Mud Lake are considerably lower than the highest canals diverting from Henry Fork in the vicinity of St. Anthony. The intervening lava fields would, however, make the construction of a canal from any point in this vicinity very expensive. From an engineering standpoint the obstacles in the way of reclaiming these lands may not be insuperable, but considered in its relation to the economic features of the problem of irrigation development in Snake River Valley the undertaking should be postponed until the irrigation possibilities of the lower valley shall have been fully determined.

Although these lands are in the Snake River Basin, and lie below the level of what may perhaps prove to be feasible points of diversion for their reclamation, they are not situated like the other irrigable lands of this valley. The surface drainage of this section is intercepted by the great lava fields, the water sinking into the rocks and reaching the river by subterranean channels at different points, mostly west of

American Falls, it being generally thought that the great springs which break out of the north wall of Snake River Canyon below Shoshone Falls have their supply in the Lost River region. If this is the case all the seepage flow which would result from the irrigation of these lands would reach the river at the same point, and would therefore not be available for use again, but would be a total loss. In the irrigation of a large tract this loss would be considerable and would alone be sufficient reason for postponing its reclamation until more is known of the storage facilities of Henry Fork and Fall River.

RESERVOIR SURVEYS.

After the investigation of the canal route referred to was finished an examination was made of the storage facilities on the upper portion of Henry Fork. A survey was made of Henry Lake with the view of ascertaining the advantages which it offers as a storage site. Another site was surveyed on Henry Fork near the Flat Rock crossing, also one near Island Park. These sites are fully described below.

Survey of Henry Lake.[a]—It was decided to make a contour survey of the lake on a line 20 feet above the present water level, with a view of determining the value of the site for reservoir purposes. The survey was begun September 15 and completed September 23, 1901, full level and topographic notes being taken.

The present area of the lake is 3,760.5 acres. The approximate area of reservoir would be 7,000 acres, with a capacity of 104,370 acre-feet. The area of the watershed is 108 square miles.

A fairly good dam site was found about 2½ miles below the head of the outlet. While the outlet at this point does not show a solid rock bottom, the sides of the canyon indicate that rock of a soft nature would be encountered by sinking a few feet. A low pass at the east end of the dam would afford an easy location for a wasteway.

The discharge from Henry Lake during the month of September, 1901, was 35 second-feet, as near as it could be measured by means of floats. The condition of the outlet channel indicates a very uniform flow, so that there would not be much variation from this amount any time during the year except during the flood season each spring. The main source of supply of Henry Fork is from great springs a few miles below the lake, which undoubtedly accounts for the great run-off estimated for this stream by the United States Geological Survey. The run-off from Fall River for 1890 is estimated at 25.16 inches, and of the Teton at 14.41 inches.[b] There are also great springs at the head of Buffalo River, Warm River, and Robinsons Fork, branches of Henry Fork. Assuming that the flood discharge of Henry Lake would average 300 second-feet during a period of sixty days, and that the average discharge during the remainder of the year is 30 second-feet, the total volume discharged would be 53,760 acre-feet. Estimating the average evaporating area of the present lake at 3,000 acres and the net loss from evaporation at 4 feet per annum, or 12,000 acre-feet, the total run-off from this watershed would be about 66,000 acre-feet, or a depth of about 12 inches, which is probably a safe estimate. The reservoir capacity provided would then be enough, probably more than necessary.

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[a] From report of Mr. D. G. Martin.

[b] Twentieth Ann. Rept., Part IV, p. 61.

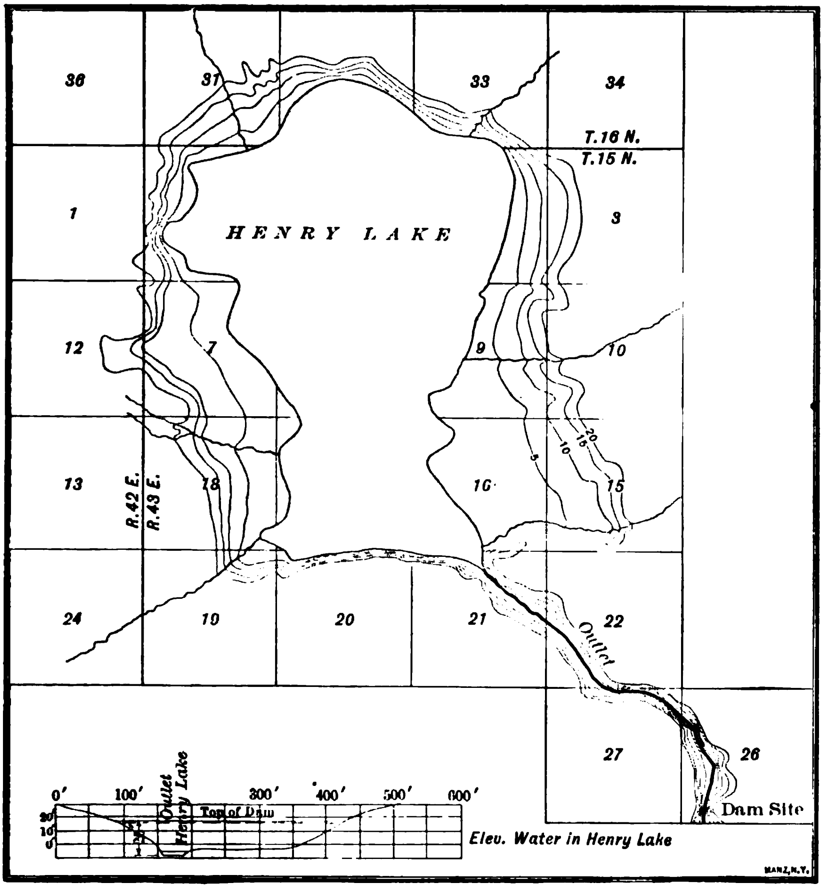


FIG. 25.—Map of Henry Lake, Idaho.

Assuming that the average area of such a reservoir would be 5,000 acres, and the net loss from this source 4 feet, or 20,000 acre-feet, there would be left for use in the reservoir, not counting any loss from seepage, 46,000 acre-feet. This reservoir would require a dam at the site selected of an average height of about 25 feet, about 250 feet long on the bottom, and about 400 feet on top.

Such a dam, if constructed of earth and gravel, would contain from 40,000 to 45,000 yards of material, and with outlet tunnel, gates, and proper cut-off walls should be built at a cost of from $20,000 to $30,000. Both timber and rock are convenient, and a dam of those materials should be constructed at a cost of from $40,000 to $50,000, probably less than $1 per acre-foot of water stored.

Henry Lake is situated in the northeast corner of the State, almost on the very summit of the continental divide, the ridge separating it from the slope of Madison River, one of the upper tributaries of the Missouri, being only about 100 feet higher than the lake, and distant about 4 miles. While the drainage basin of the lake is not great, it offers excellent facilities for the storage of a small amount of water at very reasonable cost.

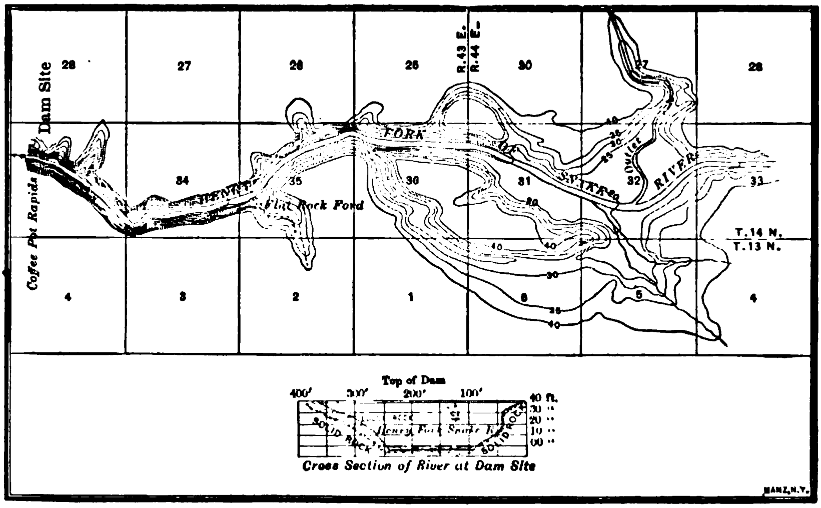


FIG. 26.—Map and cross section of Flat Rock reservoir site on Henry Fork, Idaho.

Flat Rock reservoir site.—The Flat Rock Basin is in the neighborhood of the Flat Rock crossing of Henry Fork on the St. Anthony and Yellowstone National Park wagon road. It begins about a mile above the crossing and extends up Henry Fork a distance of approximately 4½ miles. Its area is near 2,000 acres.

The site of the dam is about 2 miles below the crossing referred to, at the head of the Coffeepot Rapids. At this point the river channel is in solid rock, with a good place for a wasteway around the north end of the dam. This dam would probably be constructed of rock and timber. There is plenty of such material close at hand, and it could be easily handled.

The meander line of the basin was run at an elevation of about 6,220 feet, about 35 feet above the low-water surface of the river at the dam site. The reservoir at this level would have a capacity of approximately 35,000 acre-feet.

The discharge of the river, which was at low stage when the survey was made, was estimated at 350 second-feet. The question of the sufficiency of the water supply need not, therefore, be considered in this case; neither would any losses from seepage or evaporation have to be taken into account, as the reservoir would always be full when needed.

The dam would be about 170 feet long on the bottom and 350 feet on top and about 42 feet high from bed rock. The river would be discharged through a wasteway in the solid rock around the north end of the dam. This portion of the river is not subject to unexpected and sudden rises, and therefore it would not be necessary to carry the top of the dam very far above the surface of the reservoir. With timber and rock close at hand such a dam as would be required at this point should be constructed at a cost of from $30,000 to $40,000.

Island Park reservoir site.—The Island Park site is on Henry Fork, about 6 miles below the mouth of Buffalo Creek. This is the last site that was surveyed and is described rather fully in Mr. Martin's report, as follows:

> The locality known as Island Park lies in two sections, known as the upper and lower basins. These are separated by a narrow pass where the river cuts through a lava-rock ledge and forms rapids about a quarter of a mile in length, with a total fall in that distance of about 10 feet. As the weather was very stormy, and the season for making the survey was drawing to a close, it was decided not to attempt to make an investigation covering both basins.
>
> The lower basin being the longer, it was decided to make a survey of it alone, and with this object in view a suitable site for a dam was found at the extreme lower end of the basin, near where the National Park road from St. Anthony crosses the river. At this point the river enters the canyon through a pass in the lava about 30 feet deep. At the site selected for a dam the river has a solid-rock bottom and almost perpendicular sides, with natural wasteways on either side, as shown by cross section submitted herewith. The point selected is not suitable for a high dam, but it is my opinion that at some point farther down the canyon a good site for a high dam could be found, such as would be needed to convert both basins into one reservoir. A 30-foot dam is as high a structure as could be constructed at the point selected, so the survey was run on a contour 25 feet above the present water level in the river, with the topographic notes showing approximately the 30-foot contour.
>
> The dam could all be constructed on a solid rock bed except the portions between the wasteways and the mainland, these to be earth embankments. Material for construction is close at hand, which reduces the cost to a minimum.
>
> The area included in the site is approximately 1,200 acres, with an approximate capacity of 18,000 acre-feet. The flow of the river as gaged at the dam site was approximately 600 second-feet, thus insuring a sufficient supply for the reservoir.
>
> Should it ever develop that the construction of a reservoir at this point was an assured fact, I would recommend that a suitable site for a dam at least 50 feet high be selected farther down the canyon. This would convert both basins into a reservoir with a capacity of nearly four times the one already surveyed.

At the site surveyed by Mr. Martin the dam would be about 33 feet high and 300 feet long, with wings from 3 to 10 feet high connecting the two wasteways, which are about 700 feet apart. Mr. Martin was not satisfied with this dam site, and would have made a survey of the basins on a higher contour, as suggested in his report, but for the fact that the weather was becoming very inclement and the season was fast drawing to a close. It is quite evident, however, from this investigation, that a suitable reservoir site exists at this point, but it will without doubt have to be developed on bolder lines, as Mr. Martin suggests.

The reservoir sites above described would probably not be used for the irrigation of the lands of the lower valley, but only for the lands in the valley of Henry Fork.

From the general reconnaissance which has been made of this stream there is no question regarding the existence of storage facilities sufficient to supplement the natural water supply for the irrigation of all the lands tributary thereto. Feasible storage sites also exist on Fall and Teton rivers, especially on the former.

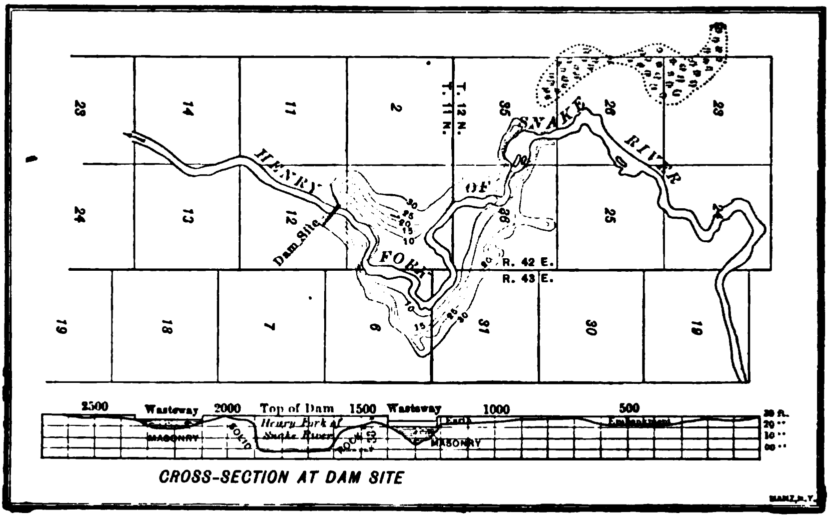


FIG. 27.—Map and cross section of Island Park reservoir site on Henry Fork, Idaho.

Most of the irrigable land, however, lies below the South Fork. This stream also furnishes most of the water for irrigation and, fortunately, the best and the most abundant facilities for storage. A brief reconnaisance of the storage facilities on the South Fork was made in 1889 by Mr. A. D. Foote, engineer in charge for the United States Geological Survey. Mr. Foote reported that Jackson Lake, which is situated just south of the Yellowstone National Park and is drained by this stream, could be made to impound 500,000 acre-feet at a cost not to exceed 20 cents per acre-foot. Another site examined by him, known as the Swan Valley, lies west of the Idaho-Wyoming boundary and just below the mouth of the Grand Canyon of the Snake. This basin is said to have an area of about 32 square miles, and by constructing a dam 125 feet in height would hold back more than 100,000 acre-feet. It is estimated this could be done at a cost not to exceed 33⅓ cents per acre-foot.

Other sites.—In order to obtain facts concerning opportunities for the construction of storage reservoirs at other localities, parties were sent out during the summer of 1902 to examine the headwaters of South Fork of Snake River and also valleys near the head of Boise and Weiser rivers. The work was planned by Mr. D. W. Ross and executed by his assistants, John T. Burke and Gilbert H. Hogue.

A small party was organized by Mr. D. W. Ross in April, 1902, for the purpose of making reservoir surveys on the headwaters of the Boise River. This party was placed in charge of Mr. J. T. Burke, and began field operations during the first week in May. Little was known regarding the possibilities of storage of this drainage system, so Mr. Burke's work was largely in the nature of a reconnaissance, although surveys were made of all basins which looked feasible for storage purposes.

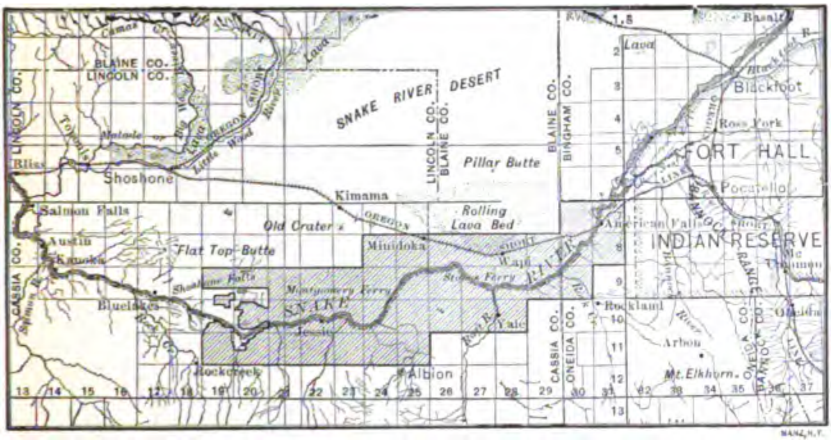


FIG. 28.—Map of lands temporarily withdrawn on Snake River, Idaho.

Surveys were made of the following sites, but the results were not encouraging, and it will probably not be found practicable to utilize any of them for storage purposes, owing to either the great height or length of dams required:

Surveys of reservoir sites on headwaters of Boise River.

Lower Smith Creek.
Upper Smith Creek.
Deer Creek (upper).
Deer Creek (lower).
Fall Creek.
Little Smoky Creek (lower).
Little and Big Smoky creeks (at junction).
South Fork of Boise River (Ross Valley site).
South Fork of Boise River (near junction with Smoky Creek).

Surveys were also made of the following sites whose utilization for storage purposes may be feasible, but the cost will be very great:

South Fork Boise River, near Joy's ranch; Middle Fork Boise River, near Alexander's ranch; Little Smoky Creek (upper).

The site on the South Fork is in T. 1 N., Rs. 7 and 8 E., Boise meridian. The canyon at the dam site is about 135 feet wide at the bottom, with a slope of nearly one to one for a height of about 140 feet, where a layer of lava about 30 feet thick, with vertical faces is found. The survey was made on a level of 170 feet above low water, the meander line being 16.6 miles in length. The capacity of the reservoir at this level is 113,411 acre-feet. This would require a dam about 180 feet in height and 600 feet long on top. The formation below the lava capping is earth and bowlders; no solid rock is in sight. While this would be a very high dam, it would not be feasible to construct one much lower, the capacity of the basin at the 100-foot level being only 38,000 acre-feet. A good wasteway can be obtained on the south side of the river, where the water can be discharged over the top of the lava sheet.

The site on Little Smoky Creek is situated about 8 miles above the junction of this creek with Big Smoky, tributaries of the South Fork. A high dam would be required in order to utilize this basin, and unless the formation at the dam site is very favorable for the construction of a cheap dam, it is doubtful if its utilization would be feasible. The capacity of the basin at the 100-foot level is 9,990 acre-feet. The top of the dam required for this depth of water would be 400 feet in length and about 30 feet wide on the bottom. Solid rock crops out at the surface at the site of the dam.

The site on the Middle Fork is near the Alexander ranch, about 60 miles above Boise, on unsurveyed land. The dam site is in a canyon cut through the solid granite, and is about 60 feet wide on the bottom and 400 feet wide on top, at a height of 95 feet above low water. This basin would have a capacity of 11,537 acre-feet.

Surveys were made of 12 basins, all told, the three just described being the only ones at all feasible. There is a question if, after further investigation, it will be found feasible to utilize the two last described.

After surveying these sites a reconnaissance was made of the entire drainage system, in order that no question could arise later on as to the existence of other sites. Nothing, however, was found which was considered worth surveying.

The work on the headwaters of the Boise River was finished during the first week of August, when investigations were begun on the South Fork of Snake River in the Jackson Hole country. Surveys were made of the following sites, which were found suitable for reservoir purposes: Shoshone Lake, Jackson Lake, Two Ocean Lake, Emma Matilda Lake, and Jenny Lake.

A line was run around Shoshone Lake 20 feet above the present water level. The lake, if raised to this level, would have a storage capacity of 166,754 acre-feet, the area of the water surface being 8,900 acres. This would require a dam 25 feet high and 650 feet long on top. This lake is situated in the Yellowstone Park and along its northwest end are many hot springs and geysers notable among the scenic features of that region. The lake's surface could be raised about ten feet without interfering in any way with these springs. At this level a storage capacity of 79,844 acre-feet should be obtained, which would require a dam about 300 feet long.

This lake has a drainage area tributary to it of about 111 square miles. The discharge at the outlet on August 26 was 100 second-feet, which would seem to insure a sufficient supply for a reservoir of the capacity last mentioned.

The survey of Jackson Lake was made on a level 20 feet above the present water surface. If raised to that level the lake would have a storage capacity of 430,100 acre-feet, and it would require a dam 4,000 feet long on top. The formation at this site is earth and solid rock, solid rock being exposed the whole width of the channel at the outlet.

No record has ever been kept of the flow of the river at this point, but its discharge on September 13, 1902, was 536 second-feet. There is no doubt but what there would be an ample water supply to fill this reservoir. The distance around the lake is 54 miles. In making the survey, however, 67.3 miles were run.

Two Ocean and Emma Matilda lakes are situated about 5 miles east of Jackson Lake. A survey was made to determine the feasibility of utilizing these lakes for storage purposes, the intention being to divert the waters of Pacific Creek, a tributary of the South Fork flowing a short distance east of these lakes, into Two Ocean Lake by means of a feed canal, whose construction was found to be readily possible. The line of a feed canal was accordingly run, connecting Pacific Creek with Two Ocean Lake. These two lakes are divided by a narrow ridge less than one-half mile in width. Emma Matilda Lake is 20 feet lower than Two Ocean Lake. The plan of connecting these lakes by a short canal was investigated and found to be quite feasible. By constructing a dam 45 feet in height at the outlet of Two Ocean Lake, the water from Pacific Creek could be stored, the surplus flowing over into Emma Matilda Lake, which could be converted into a reservoir at comparatively small expense. By carrying out such a plan as this, they could both be utilized for storage purposes. A 45-foot dam at the outlet of Two Ocean Lake would be 700 feet long on top and would impound 31,076 acre-feet. The surplus flow from this basin, as before explained, would be diverted into Emma Matilda Lake by a canal less than a half mile in length, making a cut through an earth ridge of about 12 feet. A 45-foot dam at the outlet of Emma Matilda

Lake would impound 41,000 acre-feet at the 40-foot level above present water surface. This dam would be about 375 feet long on top. Pacific Creek, which would furnish the water supply for these basins, had a discharge of 40 second-feet on October 2, 1902. There is no doubt, therefore, but what there will be an ample water supply for the purpose.

Jenny Lake is situated about 3 miles southwest of Jackson Lake. It lies at the foot of the Great Tetons, and is fed by several large streams and two or three small lakes. It contains an area of 1,214.8 acres, and if raised to a height of 20 feet above its present level, would have a storage capacity of 24,269 acre-feet. This would require a dam 25 feet in height, which would be 450 feet long on top. A measurement was made of the discharge of the outlet of this lake on October 9, 1902, when the flow was found to be 28 second-feet.

None of the dams above mentioned would be very high, although some of them would be long. An estimate has not been made of their cost, but it is Mr. Ross's opinion that their total cost would be less than $1 per acre-foot for all of the water impounded. These basins would have a combined storage capacity of 607,079 acre-feet.

After making these surveys, Mr. Burke and party proceeded to the Boise Valley for the purpose of investigating the storage facilities below the line of the upper canal on the south side of the river. Surveys were made of four basins, two of which appear to be very feasible for the purpose. These are situated from 4 to 8 miles west of Nampa, on what is known as the Deer Flat. The largest of these basins, with a 55-foot dam, would impound 45,600 acre-feet, covering 2,971 acres. The dam at the outlet would be constructed of earth. It would be about 3,000 feet long on top. The largest item of expense in connection with the utilization of this site would be right of way over lands entered prior to August 30, 1890, some of the land being in a high state of cultivation, and worth at the present time from $40 to $75 per acre. The other site lies immediately northwest of the one just described, and would have a capacity of 22,908 acre-feet, with a dam of 25 feet in height. This dam would also be of earth and would have a length on top of 3,600 feet.

After the Boise Valley surveys were completed the party was moved into the Payette Valley for the purpose of investigating the feasibility of constructing a canal taking its water from the Payette River at a point known as the Blackrock Canyon, about 6 miles above the town of Emmett, and diverting it over into the Boise Valley. A trial line was first run in order to ascertain the relative elevation of the point of diversion and the lowest saddle on the ridge between the two valleys, a point about 25 miles distant from the canyon. The first 25 miles of this canal will be on ground some of which, from 4 to 5 miles, is quite steep. The entire canal will be constructed in earth, with the exception of perhaps one-quarter of a mile near the point of diversion, where some rock will be encountered. At the crest of the ridge referred to it will be necessary to construct a tunnel perhaps one mile in length. The indications are that the ridge is composed of earth. The surveys have not yet been extended beyond the ridge, but the canal at this point will be divided into three smaller canals whose construction would be comparatively cheap and simple. Mr. Burke's party then began, in December, 1902, a topographic survey along the line of this canal for the purpose of making a more definite location and approximate estimates of cost.

If it is found feasible to construct this canal, about 50,000 acres of public lands could be reclaimed, and the water supply increased for the irrigation of about 25,000 acres more, lying under ditches which divert their water from Boise River. If a dam should be constructed at the point above referred to, about 17,000 acres lying on the north side of the Payette River could be reclaimed from this point of diversion; 100,000 acres would be benefited, all told, about 75,000 acres of which are at present without facilities for their irrigation, and the water supply for 25,000 acres more would be permanently increased.

During the early part of September a small party was organized and placed in charge of Mr. G. H. Hogue, for the purpose of making storage surveys on the headwaters of the Weiser River. Besides looking up all the available sites on this drainage, quite a careful examination was made of the conditions surrounding irrigation on all the principal tributaries of this river.

A survey was made of a storage basin in Lost Valley. This basin is situated in and around sec. 21, T. 19 N., R. 1 W., Boise meridian. This basin, with a dam 277 feet long on top and 55 feet high, holding 50 feet of water, would flood 291 acres and provide a storage capacity of 11,000 acre-feet. A dam could be constructed of loose rock and earth, there being an abundance of material of this nature available. A suitable wasteway could be constructed over a solid rock ridge on one side of the dam. Mr. Hogue estimates that the bed rock is not more than 5 feet below the surface at the center line of the dam. The water from this reservoir would probably be used chiefly upon lands in the lower end of the Weiser Valley, in the vicinity of the town of Weiser. It is not likely, however, that these lands will ever require the amount of water which this basin would be capable of storing.

A survey was made by Mr. Hogue of a reservoir basin on Crane Creek, also one on Manns Creek, and a canal line to divert the water at the latter point over into Monroe Creek, a small tributary emptying into the Weiser River near the town of Weiser. Reports and maps of these surveys have not yet been forwarded by Mr. Hogue.

On the 1st of December the two parties were joined and placed under the direction of Mr. Burke and engaged in making the Payette-Boise canal survey above referred to.

KANSAS.

In the State of Kansas practically all of the land has passed into the hands of individuals or corporations. The Government owns a million acres, but this ownership is more apparent than real, the title being in process of adjustment. Thus the reclamation of vacant public land is out of the question. Irrigation has never been practical on a large scale in this State, although widely employed in a relatively small way. The area irrigated in 1889 was 20,818 acres and in 1899 was 23,620 acres, an increase of only 13.5 per cent. The number of irrigators in 1889 was 519 and in 1899 was 929, an increase of 79 per cent, indicating that more persons are practicing irrigation and that the average size of the irrigated farm has decreased. This is due to the fact that some of the large projects reported in 1889 were abandoned in the ten-year interval before the next census. These were located along Arkansas River and on account of the irregular water supply were not successful. On the other hand, an increase in windmills and improvements in methods of pumping have led to a wide adoption of irrigation dependent upon underground sources.

Unappropriated, reserved, and appropriated lands in Kansas on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Allen			322,560	322,560
Anderson			368,640	368,640
Atchison			265,600	265,600
Barber	27,650		698,110	725,760
Barton	1,515		568,085	569,600
Bourbon			407,680	407,680
Brown			368,640	368,640
Butler	60		913,860	913,920
Chase			480,000	480,000
Chautauqua	80		416,560	416,640
Cherokee			368,640	368,640
Cheyenne	37,011	38,400	577,399	652,800
Clark	22,930		601,070	624,000
Clay			416,640	416,640
Cloud			455,040	455,040
Coffey			414,720	414,720
Comanche	6,810		501,990	508,800
Cowley			709,120	709,120
Crawford			378,880	378,880
Decatur	400	67,420	508,180	576,000

Unappropriated, reserved, and appropriated lands in Kansas on June 30, 1901—Cont'd.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Dickinson			538,880	538,880
Doniphan			232,320	232,320
Douglas			295,040	295,040
Edwards			384,000	384,000
Elk	3,191		409,609	412,800
Ellis	7,960		564,840	572,800
Ellsworth	6,840		453,960	460,800
Finney	92,785		726,415	819,200
Ford		1,900	676,500	678,400
Franklin			368,640	368,640
Geary		23,595	231,125	254,720
Gove	40,080		651,120	691,200
Graham	120	100,160	475,720	576,000
Grant	31,970		336,670	368,640
Gray	26,840		518,440	545,280
Greeley	58,400		440,800	499,200
Greenwood			739,200	739,200
Hamilton	55,750		541,370	597,120
Harper	160		518,240	518,400
Harvey			345,600	345,600
Haskell	41,980		326,660	368,640
Hodgeman	6,750		546,210	552,960
Jackson		92,160	328,960	421,120
Jefferson			358,400	358,400
Jewell		12,800	563,200	576,000
Johnson			307,200	307,200
Kearny	85,785		456,935	542,720
Kingman	40		552,920	552,960
Kiowa	14,560		446,240	460,800
Labette			415,360	415,360
Lane	19,920		440,880	460,800
Leavenworth			286,080	286,080
Lincoln			456,320	456,320
Linn			407,680	407,680
Logan	58,640		627,440	686,080
Lyon			549,120	549,120
McPherson			576,000	576,000
Marion			610,560	610,560
Marshall			576,000	576,000
Meade	13,480		610,520	624,000

Unappropriated, reserved, and appropriated lands in Kansas on June 30, 1901—Cont'd.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Miami			376,320	376,320
Mitchell	160	13,760	443,680	457,600
Montgomery			411,520	411,520
Morris			432,640	432,640
Morton	95,920		370,640	466,560
Nemaha			460,800	460,800
Neosho			368,640	368,640
Ness	9,340		681,860	691,200
Norton	160	48,240	527,600	576,000
Osage			460,800	460,800
Osborne	2,400	59,200	511,200	572,800
Ottawa			455,680	455,680
Pawnee			476,160	476,160
Phillips	2,040	33,280	540,680	576,000
Pottawatomie			537,600	537,600
Pratt			460,800	460,800
Rawlins	19,135	53,760	618,305	691,200
Reno			797,440	797,440
Republic			454,400	454,400
Rice	1,720		452,680	454,400
Riley			386,560	386,560
Rooks	7,320	36,320	532,360	576,000
Rush			460,800	460,800
Russell			569,600	569,600
Saline			455,680	455,680
Scott	37,440		423,360	460,800
Sedgwick			634,880	634,880
Seward	87,965		326,755	414,720
Shawnee			350,720	350,720
Sheridan	4,280	156,160	415,560	576,000
Sherman	28,280	47,360	615,560	691,200
Smith		32,000	544,000	576,000
Stafford			506,880	506,880
Stanton	25,960		404,120	430,080
Stevens	59,120		406,800	465,920
Sumner			753,920	753,920
Thomas	4,200	168,640	515,800	688,640
Trego	8,680		567,320	576,000
Wabaunsee			507,520	507,520
Wallace	63,110		512,890	576,000

Unappropriated, reserved, and appropriated lands in Kansas on June 30, 1901—Cont'd.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Washington			576,000	576,000
Wichita	19,560		441,240	460,800
Wilson			368,640	368,640
Woodson			317,440	317,440
Wyandotte			97,920	97,920
Total	1,138,497	985,155	50,164,348	52,288,000

The above shows the condition on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Owing to the exhaustion of public lands, the funds for use in Kansas are small. There are in the western end of the State localities where storm waters may be stored, or a moderate supply obtained from underground, for the reclamation of lands in private ownership. The most important matter in this connection is the careful study of the quantity of water which may be obtained from wells, and of the methods by which this may be made available for industrial purposes. The quantity and quality of this water are to a certain extent dependent upon geologic phenomena, and a careful mapping of the geology is one of the requisites for a full knowledge of the opportunities of practically utilizing the supply.

The river of chief importance in irrigation in Kansas is the Arkansas. This river rises in Colorado, and in that State most of its waters are employed in irrigation. The river is frequently dry long before it reaches the Kansas line; floods, however, pass down the river through western and southern Kansas into Indian Territory.

At various points along Arkansas River east of the Colorado line attempts have been made to introduce irrigation on a considerable scale; large ditches have been constructed on both sides of the river, notably the north side, in the vicinity of Syracuse, Garden, and Dodge. The erratic character of the water supply discouraged the farmers along these canals, and this, in connection with various unfortunate circumstances of operation or financial management, resulted in the practical abandonment of the works. To be successful some form of storage must be provided for these irrigation streams.

Although the channel of Arkansas River is frequently dry in western Kansas, the valley lands contain water which rises within 10 feet, or even less, of the surface. The amount of water in the saturated sands and gravels is very large; ordinary pumps can not exhaust it; and according to the popular belief there is an "underflow" following the general trend of the river.

Examinations of this so-called "underflow" show that its movement, if any, is extremely slow—not more than a few feet a day, except in layers of cobblestones. In order to construct works to bring this water to the surface by gravity or by pumping it is necessary to know more of the direction and rate of movement of this water. Experiments have been begun in this direction, with the object of obtaining facts upon which to base plans or devices for utilizing this water if practicable. Although the surface of the country may not afford facilities for water storage, it is believed that the sands and gravels under ground perform this office to a certain extent, and that ultimately a feasible scheme may be devised for making use, on a large or small scale, of these resources.

The deeper-lying waters of the State are in some localities artesian in character; that is to say, when penetrated by a drill they rise in the well and overflow the surface. The limits of the artesian basin can be defined in part by careful geologic examination and in part only by deep experimental drilling. In order to avoid waste of money in making such drillings it is essential to learn all of the facts as fully as possible and, guided by these, to choose the localities where deep wells can be sunk to the best advantage. To locate and sink these wells without obtaining this preliminary knowledge is venturing in the dark and neglecting the light which might be had. During the summer of 1902 Mr. N. H. Darton, geologist, has been devoting much time to outlining the probable artesian areas and has obtained material for a general report upon the Great Plains.

MONTANA.

This State offers some of the best opportunities for reclaiming arid lands. The water supply is large, particularly in the Upper Missouri and Yellowstone rivers. There are known to be a number of reservoir sites where floods can be stored, and vast tracts of arid land stretching from the foothills of the Rocky Mountains out easterly across the High Plains.

Many projects for reclamation have been discussed. Most prominent among these is the project of utilizing the waters of the northern Rocky Mountain region, which flow to waste in St. Mary River. This is the most northerly project in the United States. South of this is what is known as the Sun River project, which was examined in 1889 and 1890 by the Powell irrigation survey, the work being under the direct charge of Mr. Herbert M. Wilson. The results are shown in the Twelfth Annual Report, Part II. Farther south and toward the headwaters of Missouri River are opportunities for taking out some water which now flows to waste and which can be conducted to valley lands in the vicinity of Helena, the State capital. Again, farther south and east is Yellowstone River, which flows between broad bench lands upon which water may be taken. There is thus no lack of enterprises, some of which will undoubtedly prove to be feasible and worthy of consideration. The table below gives, by counties, the area of vacant public land on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

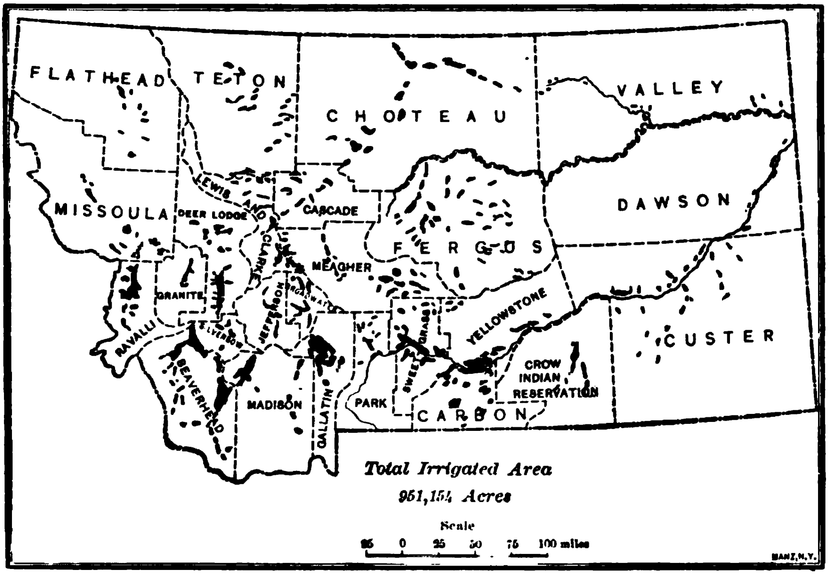


FIG. 29.—Map of irrigated areas in Montana.

Unappropriated, reserved, and appropriated lands in Montana on June 30, 1901.

County.	Area unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Beaverhead	2, 376, 297	2, 800	497, 063	2, 876, 160
Broadwater	569, 585	....	228, 495	798, 080
Carbon	1, 375, 470	....	206, 610	1, 582, 080
Cascade	657, 591	47, 520	1, 063, 849	1, 768, 960
Choteau	8, 311, 182	790, 250	1, 169, 928	10, 271, 360
Custer	11, 250, 366	547, 680	1, 315, 554	13, 113, 600
Dawson	7, 578, 203	170, 560	716, 517	8, 465, 280
Deerlodge	163, 841	....	112, 159	276, 000
Fergus	4, 405, 729	143, 011	1, 165, 180	5, 713, 920
Flathead	3, 975, 002	386, 000	1, 027, 158	5, 388, 160
Gallatin	607, 881	....	1, 045, 239	1, 653, 120

Unappropriated, reserved, and appropriated lands in Montana on June 30, 1901—Cont'd.

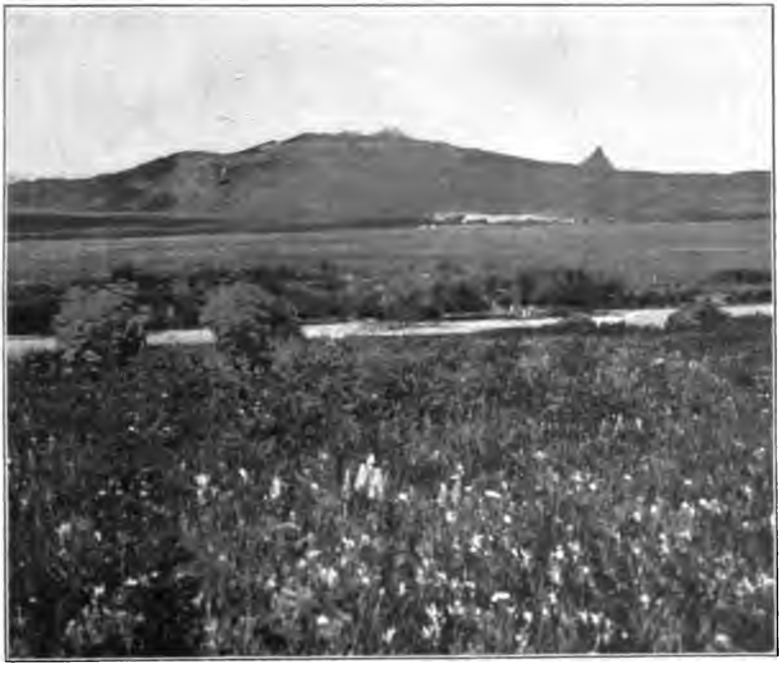
County.	Area unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Granite	922, 763		64, 757	987, 520
Jefferson	782, 659		231, 741	1, 014, 400
Lewis and Clarke	882, 442	716, 670	599, 928	2, 199, 040
Madison	2, 248, 524	20, 550	574, 446	2, 843, 520
Meagher	1, 870, 814	42, 027	809, 079	2, 721, 920
Missoula	2, 044, 563	1, 333, 333	708, 504	4, 086, 400
Park	1, 344, 665		439, 665	1, 784, 320
Powell	584, 203	599, 040	709, 077	1, 892, 320
Ravalli	720, 735	691, 200	361, 505	1, 773, 440
Silverbow	537, 880		113, 000	650, 880
Sweet Grass	1, 229, 752	15, 360	602, 568	1, 847, 680
Teton	2, 739, 820	1, 557, 000	559, 500	4, 856, 320
Valley	6, 095, 632	2, 361, 920	97, 968	8, 555, 520
Yellowstone	1, 326, 798	24, 320	1, 023, 282	2, 374, 400
Crow Indian Reservation		3, 504, 000		3, 504, 000
Total	64, 602, 397	12, 953, 241	15, 442, 762	92, 998, 400

The lands at present irrigated in Montana are widely scattered throughout the State, the largest areas being in the mountain valleys in the central and western portion.

The total area irrigated in 1899 was a little less than 1,000,000 acres, being 951,154 acres. Ten years earlier only 350,582 acres were irrigated. Owing to the far northern position of the State and the opportunities offered for summer grazing on the broad plains and extensive mountain slopes, the principal crops raised are those needed for winter feed of cattle and sheep. Over one-half of the irrigated acreage is in wild or prairie grasses, next to this in importance being the tame and cultivated grasses, alfalfa, and grains cut green for hay. Orchard and small fruits are successful in some of the valleys, but hay is and probably always will be the chief agricultural product.

It must not be supposed, because of the northern location, that the climate is rigorous. On the contrary, the elevation of the land as a whole decreases toward the north. The High Plains of western Kansas and western Nebraska, swinging around through the Dakotas, diminish in altitude as they approach the Canadian line, so that even in northern Montana, along Missouri River, the land is at a lower elevation than it is in western Kansas. For this reason the climate is relatively mild and the crops of the Temperate zone are successfully produced.

A. VIEW OF UPPER ST. MARY LAKE, MONTANA.



B. VIEW OF ST. MARY DAM SITE, MONTANA.

MILK RIVER PROJECT.[a]

The main range of the Rocky Mountains crosses west of the center of Montana, with a generally southeasterly trend. Just south of the international line between Canada and the United States are high snow-capped peaks, from which issue a number of streams, flowing easterly to the foot of the mountains. Here their course is checked by great deposits of gravel and débris which have come down from the north during the incursions of the ice of glacial times. Lakes have been formed by this mass of material, and the rivers which may have formerly continued east across the plains are diverted and turned north. As a consequence the channels which extend far easterly from the foot of the mountains do not receive the waters from the high peaks, but obtain only a small amount of water from the local rainfall upon the undulating High Plains.

The largest of the lakes near the international boundary are those at the head of St. Mary River. This stream, intercepting the mountain drainage, skirts along the front of the range and, flowing northward, passes into Canada, the waters being lost finally in Hudson Bay.

It has long been the desire of citizens of Montana to utilize this waste water, conducting it from the outlet of St. Mary Lakes easterly across the rolling divide to the lands on the Great Plains. Preliminary examinations have shown this to be feasible, and that the waters coming from the mountains can be conducted eastward along the course which they would naturally be supposed to take, illustrating what may be assumed to have been the conditions which existed before the glacial incursion diverted their course.

Most of the water that flows from the rolling country east of the mountains gathers in channels which unite to form Milk River. This flows northeasterly across the line into Canada, and continues in a general course parallel with the international boundary, then crosses back into Montana, and finally flows into Missouri River. The broad valley of Milk River in Montana consists of gently rolling country, well adapted to irrigation. The water supply from the river is, however, deficient, owing to the lack of high mountain areas at its headwaters. It is proposed to connect these headwaters with the mountain area.

The turning of the flood or excess water from St. Mary Lakes easterly into the head of Milk River is a comparatively small matter. The divide is low and can be crossed by a gravity canal. The problems to be solved lie not in the storage of water in St. Mary Lake and the taking of this eastward, but in the complications which ensue owing to the presence of the international boundary and the alternative projects which must be considered in selecting the lands to be reclaimed. In round numbers at least 200,000 acres might be irrigated. With supplemental storage on the plains this can be increased. The question at

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[a] From report by Cyrus C. Babb.

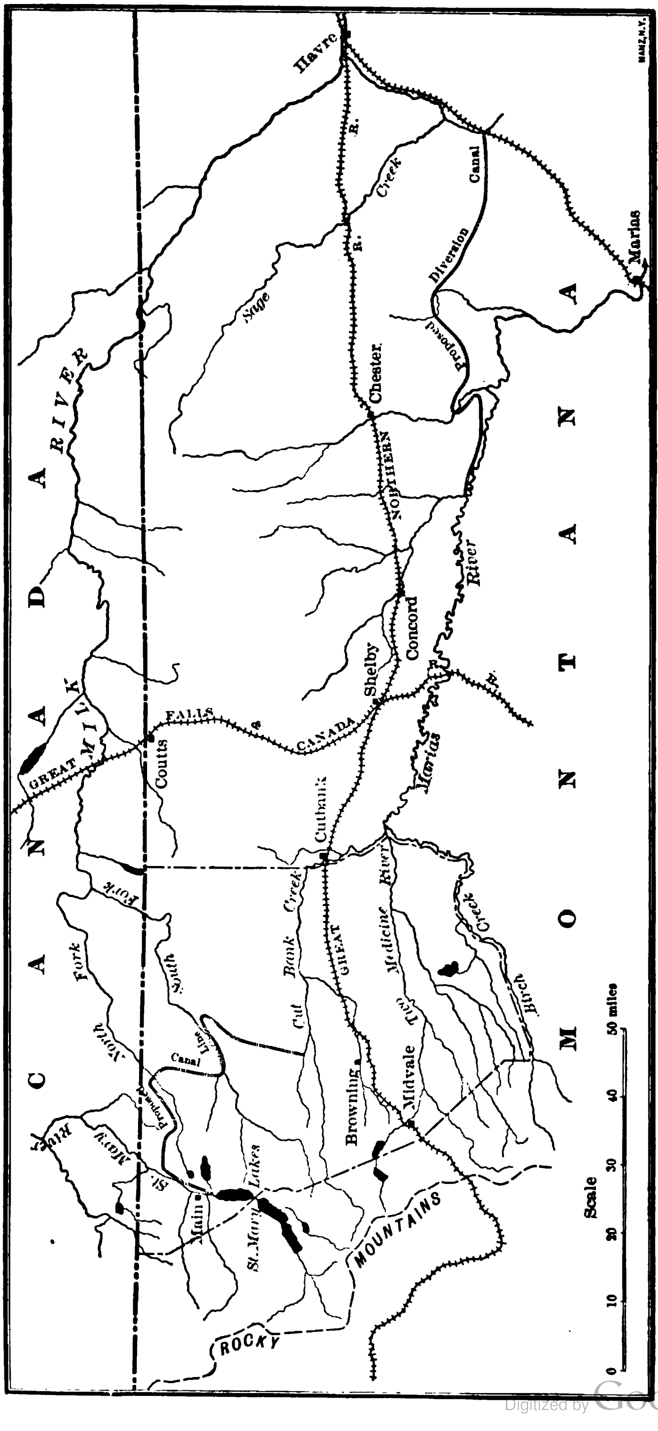
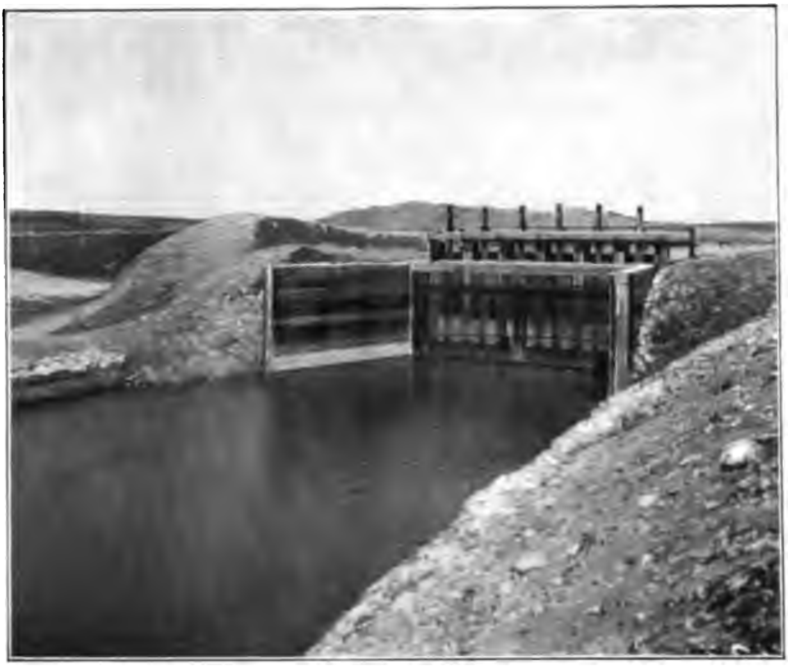
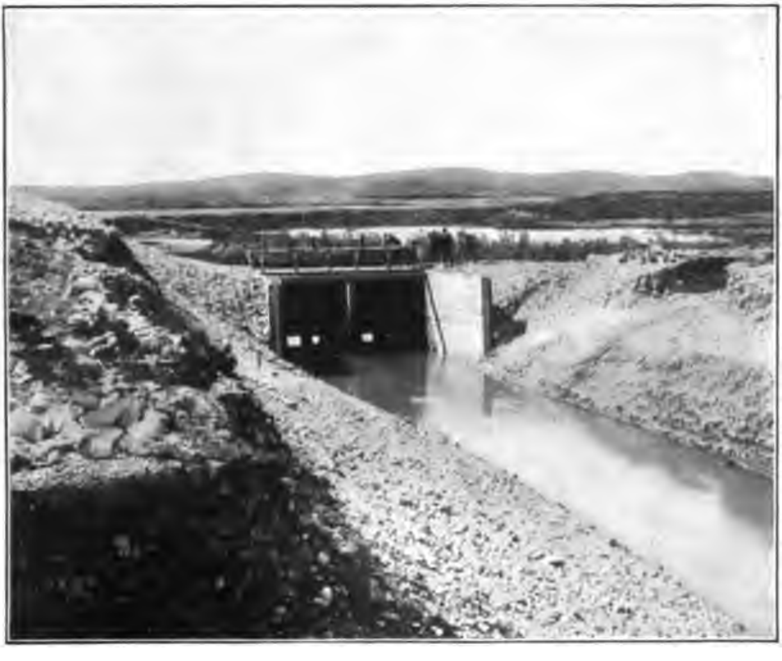


FIG. 30.—Map of Milk River Basin.



A. UPPER SIDE HEADGATE, CANADIAN AND NORTHWESTERN CANAL COMPANY.



B. LOWER SIDE HEADGATE, CANADIAN AND NORTHWESTERN CANAL COMPANY.

once arises, Should this water be used as near as possible to where it is obtained for the irrigation of the higher lands, or should it be taken

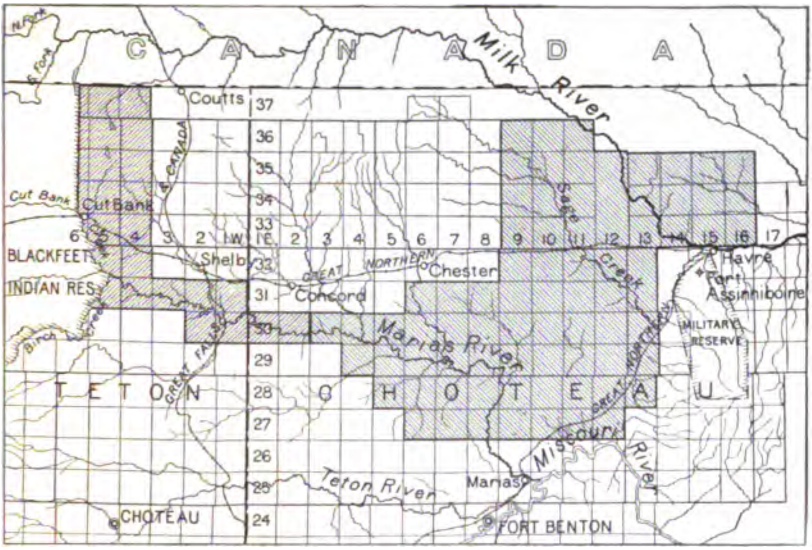


Fig. 31.—Map of lands temporarily withdrawn on Marias and Milk rivers, Montana. (Portions of lands reserved have been restored since map was drawn.)

easterly down the plains and employed on more valuable lands at a lower altitude? If the water is to be taken farther east, should it be

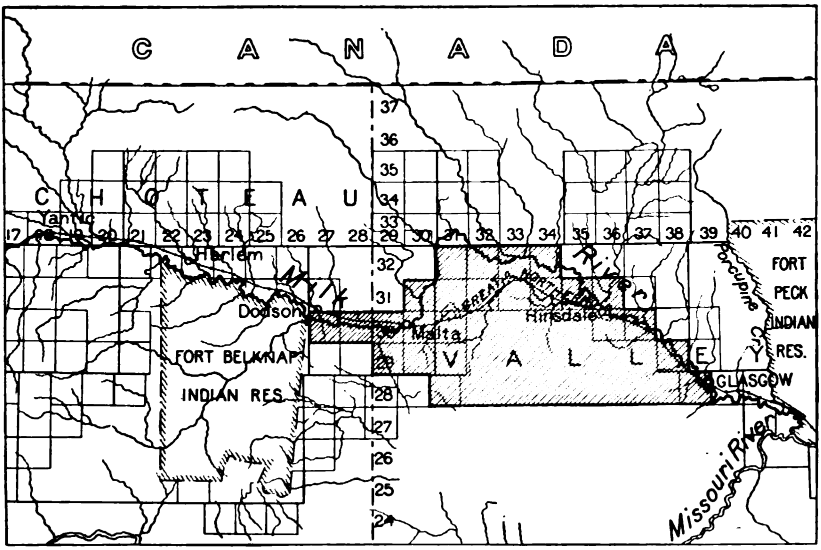


Fig. 32.—Map of lands temporarily withdrawn near Malta, Mont. (Additional lands have been reserved since this map was drawn.)

allowed to flow down Milk River through Canada, or can it be taken at reasonable cost, in canals, south of the international boundary?

If it flows down Milk River, can or will the Canadians divert it before it can enter the United States?

Satisfactory answers to these questions, and the determination of which of the alternative ways is best, necessitate a thorough knowledge of the situation, such as can be had only by careful surveys.

An examination of St. Mary lakes and rivers was begun in 1900 by Mr. Gerard H. Matthes, and it was ascertained that a diversion canal could be carried over the divide to the headwaters of Milk River. In the summer of 1901 Mr. Cyrus C. Babb continued the work and ran out a cross-country line to obtain facts as to the cost of a canal south of the boundary. He found that this was impracticable owing to the great length, over 250 miles, and its cost, $4,000,000 or more. This being settled, three courses were open for consideration:

First. Carry water from St. Mary Lake to the North or South Fork of Milk River and allow it to run through Canada to the lower Milk River Valley in Montana.

Second. Utilize the water on lands as far west as possible, thus irrigating the eastern section of the Blackfeet Indian Reservation and lands immediately adjacent on the east.

Third. Carry water from the head on St. Mary River across both the North and the South Fork of Milk River to Cutbank Creek, down which it will flow to Marias River, 100 miles or more, and take it out of the Marias by a canal to Big Sandy Creek, a tributary of Milk River. Each of these courses has been taken up in the survey made during 1902, and other details also were considered.

A reconnaissance was made down Milk River in Canada to ascertain whether water could be taken out of that river on this course. It was evidently impracticable to do this, except at or near the gap through which the Great Falls and Canada Railroad passes. It is probable that such a diversion can not be made, but this can be determined only through a careful survey in that part of Canada.

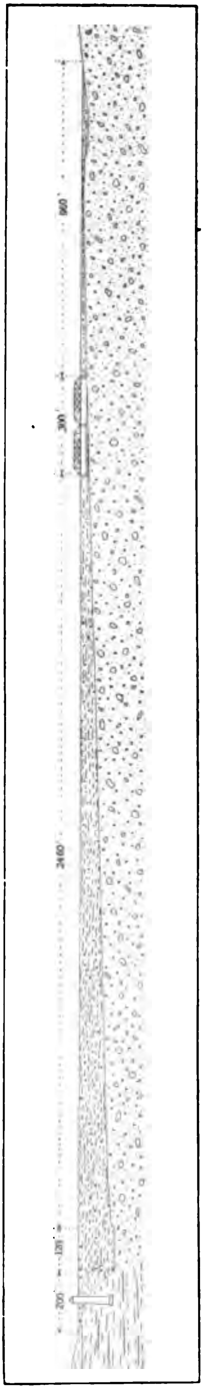
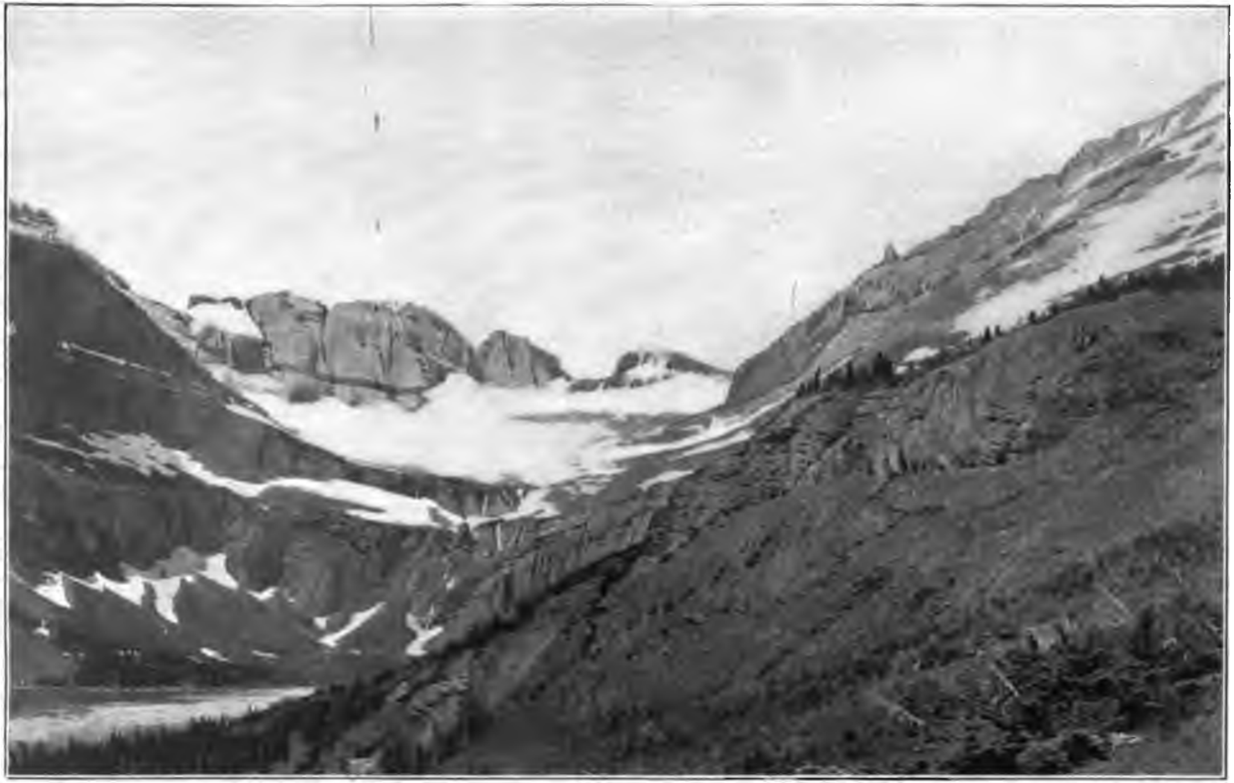


FIG. 33.—Elevation of proposed St. Mary dam.



GRINNELL GLACIER AND HEAD OF SWIFTCURRENT CREEK, MONTANA.

At the close of field work in 1902, sufficient knowledge of the country had been obtained to describe and withdraw from entry certain lands that would probably be irrigated on the completion of the project. The Marias and Milk river segregation is shown in fig. 31. The area withdrawn in the vicinity of Malta is shown in fig. 32.

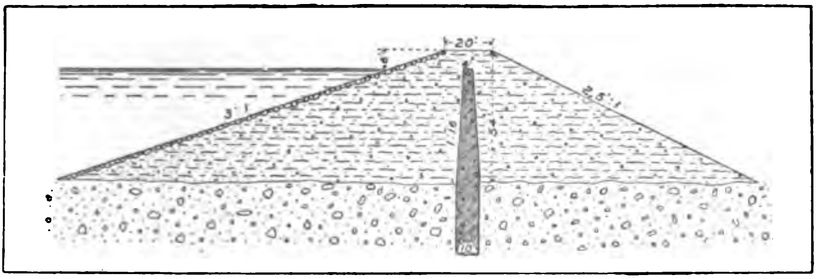


FIG. 34.—Cross section of proposed St. Mary dam.

Measurements of the outflow of St. Mary Lakes were taken on July 14, 1901, and the daily discharge has been computed. It was found that in August the river decreased from 1,574 second-feet the first of the month to 653 second-feet at the close, with a mean of 932 second-feet. As the diversion canal from this stream is designed to carry 1,380 second-feet at its head, recourse must be had to storage in order to maintain a constant supply. During 1901 the total discharge of St. Mary River at Main, Mont., including the discharge of the main river at the outlet of the lake and also that of Swiftcurrent Creek, was 728,124 acre-feet, while in 1902 it was 678,422 acre-feet.

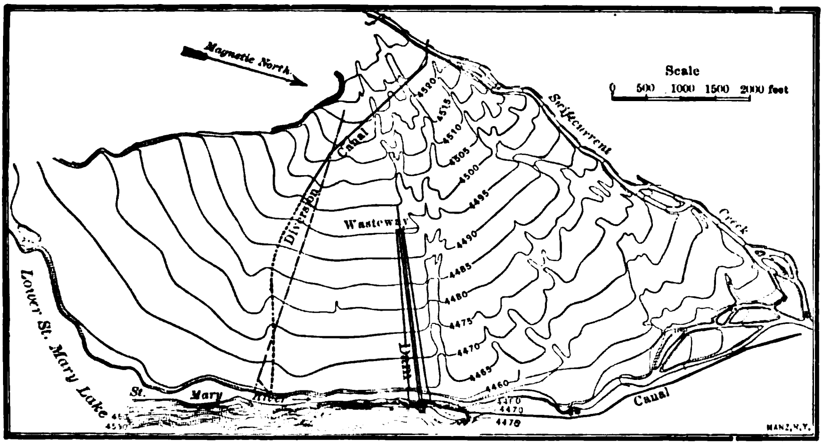


FIG. 35.—Contour plan of St. Mary dam site.

It is proposed to build a low storage dam about three-fourths of a mile below the present outlet of Lower St. Mary Lake. (See fig. 35.) This dam will have a maximum elevation of 50 feet above the bottom of the river, and will form a reservoir with a capacity of 250,000 acre-feet. The top of the earthen dam will be at an elevation of 4,513 feet above sea level. The total length of earth embankment is 2,650 feet. The inner slope will be 3 to 1 and the outer slope 3 to 1. It is the intention to use the hydraulic-fill method of dam construction. Most of the material will come from the hill west of the dam, as the water to wash it down can easily be obtained from Swiftcurrent Creek by means of a diversion canal about 2 miles long.

During 1902 a boring and diamond-drill party explored for bed rock at the dam site, with the following results:

Results of drill borings at St. Mary dam site.

Hole No.	Distance from east end of dam.	Depth.	Remarks.
	Feet.	*Feet.*	
1	389	26.9	Bed rock, west bank river.
2	700	79.6	Bed rock.
3	1,000	119.7	Bed Rock, probably.
4	1,300	....	Shaft, 21 feet to water.
5	1,600	157.9	Bed rock, probably.
[a]6	1,300	105.0	Rock not reached.
[b]7	1,000	57.5	Do.

[a] On B line, 1,000 feet above or south of main line of dam.

[b] On C line, 2,000 feet above or south of main line of dam.

The total content of the dam will be 585,864 cubic yards. A core wall will probably be built of concrete at the eastern end and of puddled earth at the western. The designs and cost of this are not completely worked out, but will bring the total cost of the dam to about $250,000.

It is proposed to locate the spillway, not in the river channel at the eastern end of the dam, but at the western end, at an elevation of 4,500 feet. The elevation of the ground at the western end of the dam is 4,496 feet, and it will be necessary to build a riprap spillway 350 feet in length, ranging in height from 4 feet at the eastern end, where it joins the dam, to zero at the western end, where it intersects the 4,500-foot contour.

From the reservoir thus formed water will be diverted through an open cut in the right bank of the river. The formation of the right bank is sandstone. The flow of the water will be controlled by gates placed in a circular cement wall of 30 feet radius.

The canal proper will begin at the end of the open cut. The grade was assumed at two-hundredths of 1 per cent, or a fall of 1.056 feet to

VIEW OF KENNEDY CREEK, MONTANA.

the mile. It is proposed to make the bottom width 30 feet, with a 10-foot depth of water, and with side slopes of 1 to 1. It is assumed that in a canal of these dimensions the mean discharge at the head will be 1,380 second-feet. From the dam the canal line will continue down the east bank of the river a distance of 7 miles, then turn eastward and pass through a gap known as Spider Lake Gap. Thence it will continue in a general northeasterly direction for a distance of 27.4 miles, or to the North Fork of Milk River. The last step in the con-

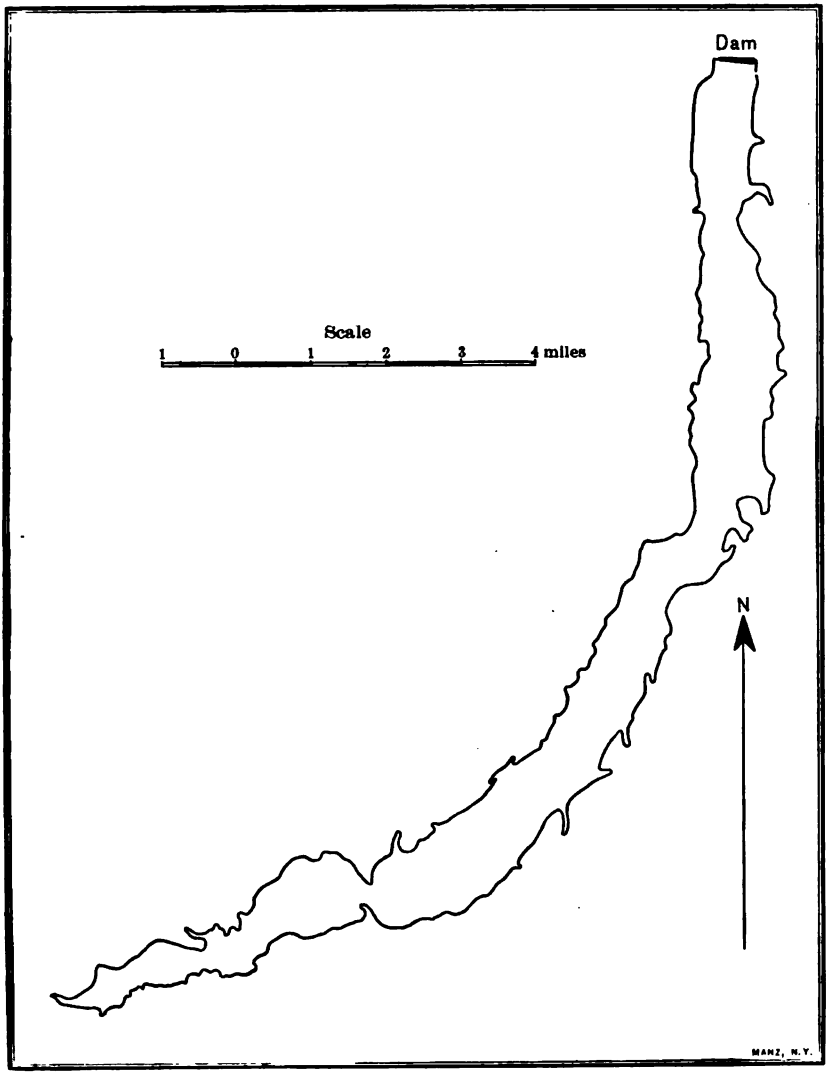


FIG. 36.—Map of St. Mary reservoir site.

struction of the canal to reach the North Fork will be the dropping of the water 180 feet to the level of the creek.

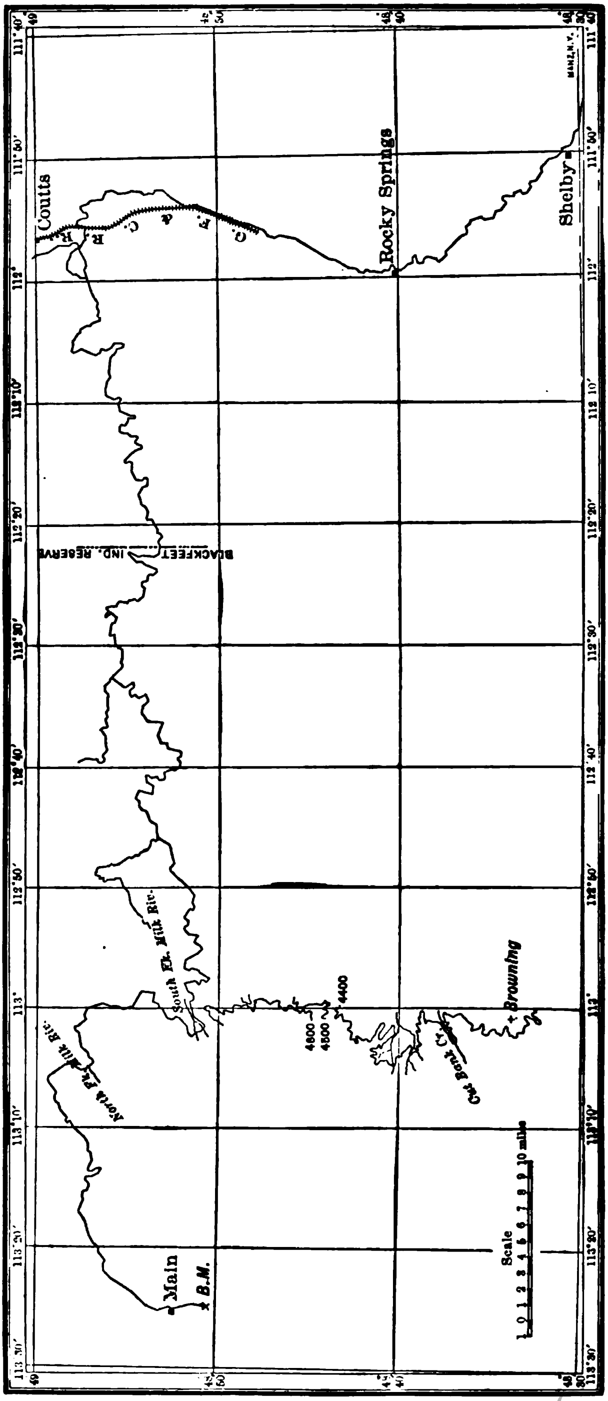
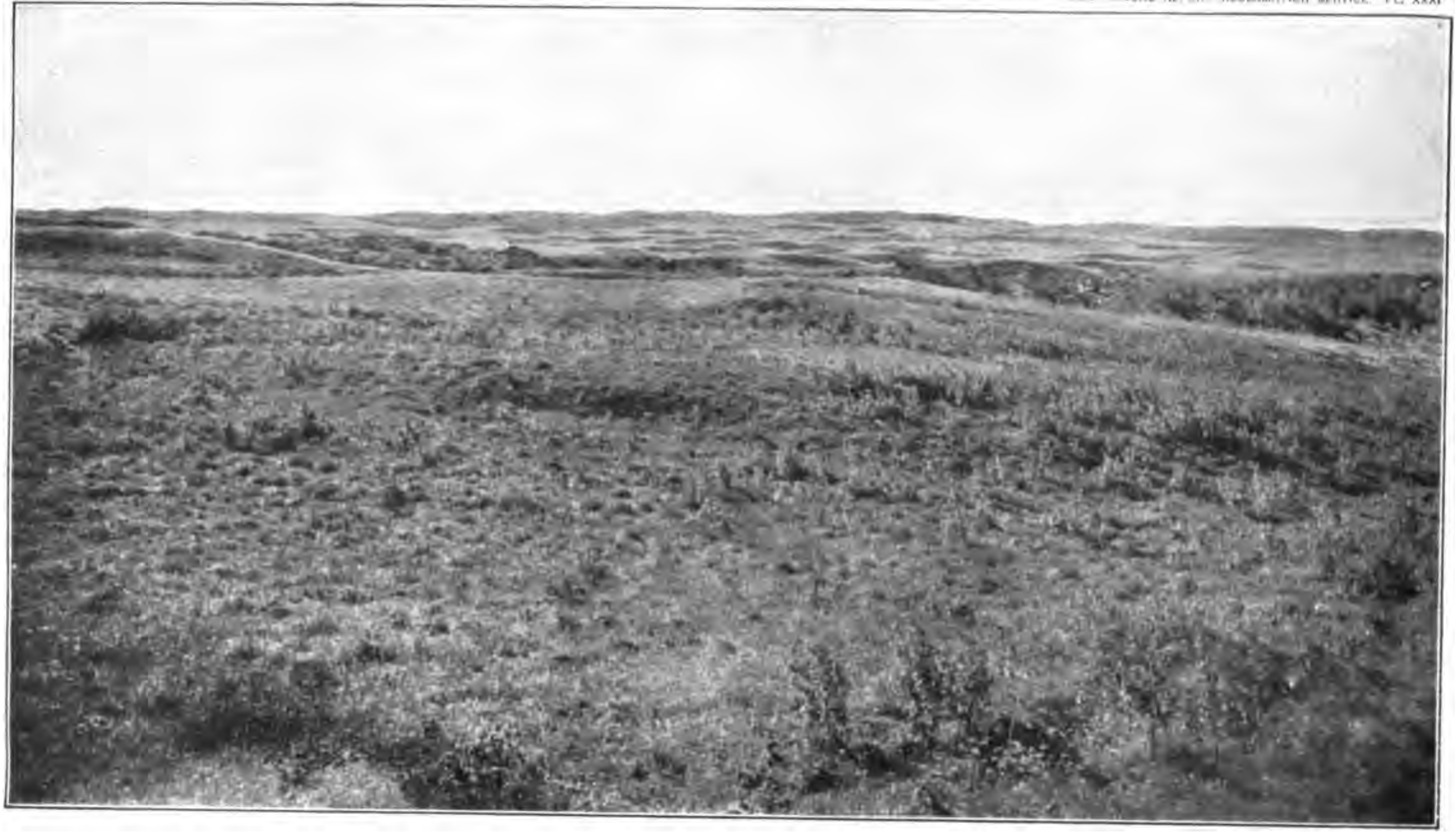


FIG. 37.—Map of St. Mary canal line.



TOPOGRAPHY ALONG CANAL LOCATION LEADING FROM ST. MARY RIVER, MONTANA.

The following table gives the estimated cost of construction of this portion of the line, dropping the water to the North Fork, as described:

Estimated cost of St. Mary dam and canal to North Fork of Milk River.

Dam and head gates	$250,000
Head to Spider Lake	245,100
Spider Lake to drop at North Fork	288,400
Drop at North Fork	16,040
Two sets of waste gates on line	4,000
	803,540
Engineering and contingencies	120,530
Total	924,070

Instead of dropping the water into the North Fork, it could be carried across that stream by means of a pressure pipe or inverted siphon. The invert of the siphon would be 181 feet and the horizontal distance from the intake to the outlet 2,638 feet. It is proposed to carry the water across through three pipes each 7 feet in diameter. The fall from the intake to the outlet will be 6.2 feet, the inverted siphon to be of wooden stave pipe, as siphons of that character have been found very successful for engineering purposes in the West. The cost of this inverted siphon will be about $67,000.

Seven miles beyond the North Fork the canal would pass through what is known as McLeod Gap, where occurs the greatest depth of excavation on the entire line, amounting to 167 feet. A few miles beyond, the water could be turned into the South Fork of Milk River, making the total length of the canal and siphon from the head on St. Mary River 43.8 miles. The following table shows the estimated cost of this line:

Estimated cost of St. Mary dam and canal to South Fork of Milk River.

Dam and head gates	$250,000
Head to Spider Lake	245,100
Spider Lake to North Fork of Milk River	288,400
Two sets of waste gates	4,000
Siphon, North Fork	67,000
North Fork to South Fork of Milk Rivers	360,800
	1,215,300
Contingencies	121,530
Engineering	60,770
Total	1,397,600

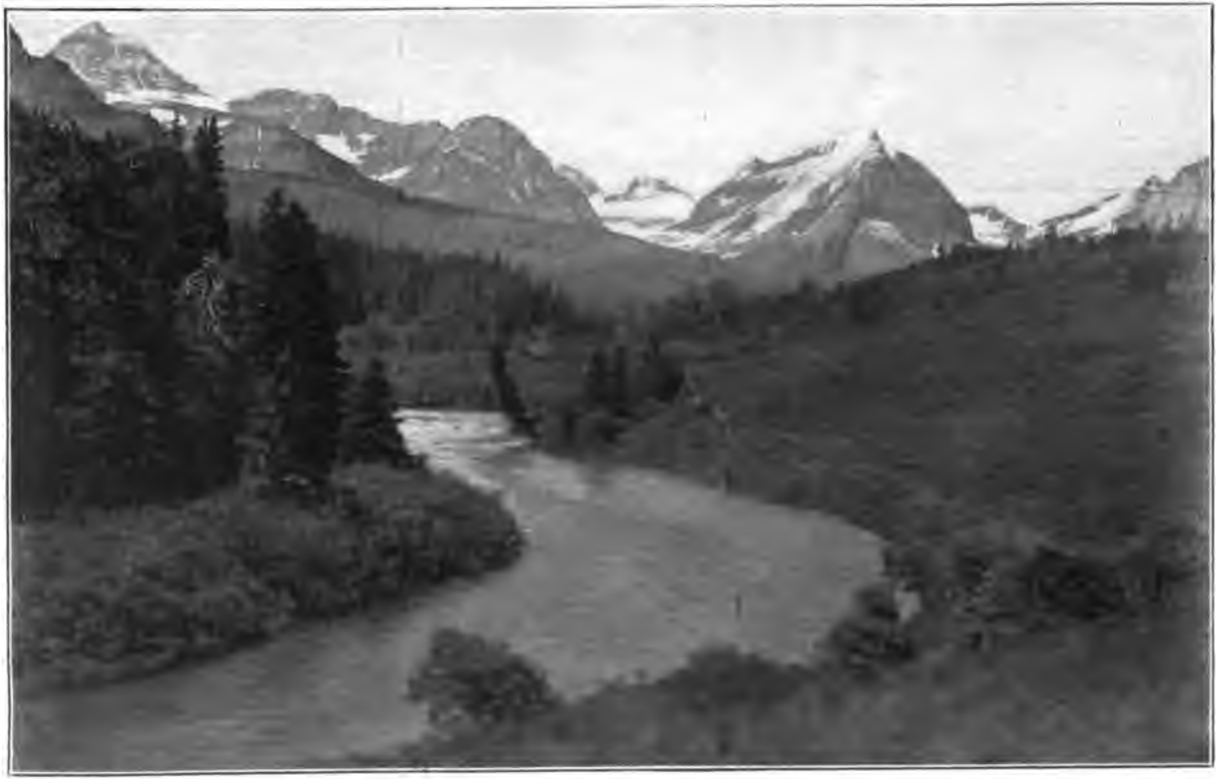
If the waters are permitted to enter the North Fork or the South Fork, they will find their way into Canada before they can be used in the lower valley of Milk River, but it is believed that they can not be diverted in Canada before they return to the United States. If it is desired to keep the water in the United States, the canal would have to be extended farther east. For this extension several routes are available. After crossing the South Fork the canal would continue in a general northeasterly direction for 19.3 miles, until the ridge separating the Milk River and Marias River drainages is passed. At that point two routes are offered: (1) Continue the line in a general easterly direction, approximately paralleling the international line, for a distance of 200 miles, until Sage Creek, a tributary of Lower Milk River, is reached; (2) bend the line southward and continue it for 25.9 miles, until Cutbank Creek is reached, the water to continue down that stream for 100 miles, more or less, being diverted again near the mouth of Willow Creek and carried in an artificial channel for a distance of about 75 miles, until it is turned into Big Sandy Creek, a tributary of Sage Creek.

During 1901 a line was surveyed on the first-mentioned plan—that is, with a general easterly direction. Sixty-four miles from the head of the canal the line came to the top of a bluff, over which it would be necessary to make a drop of 205 feet. Twenty-three miles beyond that point another bluff was reached, and a second drop of 136 feet would be required. It was found that throughout the remainder of the length it would be necessary to make similar drops, varying from 15 feet to more than 300 feet, due to the great fall of the country through which the line passed.

Sage Creek was not reached during the survey of the last season, but sufficient work was executed to show that a canal more than 250 miles in length would be necessary and that the cost of construction would be prohibitive; also, on account of its great length, a very large percentage of the water taken in at the head would be lost by seepage and evaporation before the lower country was reached. The following is a rough estimate of the cost of this line from the head on St. Mary River to Sage Creek:

Estimated cost of St. Mary dam and canal from the head to Sage Creek.

Dam and head gates	$250,000
Head to North Fork of Milk River	533,500
Two sets of waste gates	4,000
Inverted siphon	67,000
North Fork to South Fork of Milk River	360,800
Regulating gates at South Fork	5,200
South Fork to first drop, 20 miles, at $12,000	240,000
First drop	20,000
First drop to second drop, 22.7 miles, at $10,000	227,000
Second drop	20,000
Second drop to reservation boundary, 22.7 miles, at $15,000	340,500
Reservation line to Great Falls and Canada Railroad, 35 miles, at $12,000	420,000
Drops Nos. 3 to 8 (six), at $5,000	30,000
Siphon railway coulée	280,000
Great Falls and Canada Railroad to Sage Creek, 100 miles, at $12,000	1,200,000
	3,996,000
Contingencies and engineering	604,000
Total	4,600,000



SWIFTCURRENT CREEK, MONTANA.

The line just described is not considered feasible on account of its length and the great cost of construction. From a study of last season's work, taken in conjunction with topographic and general maps, a more feasible route may have been found. It is to turn the water into Cutbank Creek and redivert it from Marias River, 100 miles or more below, and thence carry it to Big Sandy Creek, a tributary of Milk River.

During 1902 parties were investigating the possibility of storage in the upper basin of the Marias, while other parties were making surveys of the lower Marias, in order to find, if possible, a point where a feasible diversion could be made for a canal to Big Sandy Creek. The reconnaissance for reservoir sites was disappointing in that no large sites were found. Two Medicine Lake was the most practicable one. The following table shows the capacities for different heights of dam:

Capacity of Two Medicine Lake reservoir site, Montana.

Contour.	Area.	Capacity of sections.	Total capacity.	Top length of dam.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*	*Feet.*
4,850	1.5	0	0	....
4,854	352.5	708	708	65
4,860	538.4	2,673	3,381	172
4,870	722.7	6,305	9,686	453
4,880	854.0	7,884	17,570	700
4,890	1,004.5	9,293	26,863	960
4,900	1,100.8	10,527	37,390	1,225
4,910	1,187.3	11,441	48,831	1,505
4,920	1,260.3	12,238	61,069	1,640
4,930	1,330.2	12,952	74,021	1,940
4,940	1,393.1	13,617	87,638	2,150

The total annual yield of the stream approximates 100,000 acre-feet. The detailed estimates on the project have yet to be worked up in this office. A few smaller sites were found, but the cost of construction of the necessary regulating works would exceed the value of the water stored at the present time.

A topographic map of Marias River Canyon on a scale of one-fifth mile to the inch, and with a contour interval of 20 feet, has been made from the crossing of the Great Falls and Canada Railroad to below the mouth of Cottonwood Creek. The river is in canyon for its entire length, and has a fall not exceeding 5 feet to the mile. The general features of the best diversion from this stream can be studied on this map. Without it many preliminary locations might be run and yet it would not be known whether the best location had been found.

Milk River is bounded by high cliffs on either side, 200 feet more or less in elevation, from where it crosses the international line and enters the United States for the last time down to Yantic, 10 miles east of Havre. At the latter point the valley broadens, and the relative heights of the bluffs decrease, and there is to be found here opportunity for diversion to the agricultural lands of the Lower Milk River Valley. A map of this vicinity is being made, and a study of this will show the extent of the land that can be reclaimed, and the general locations, grades, and sizes of the diversion canals.

During the season surveys have also been made of a diversion and storage project farther east. The plan contemplates diverting Milk River at a point a short distance above Malta and storing in Lake Bowdoin, a body of alkali water 8 miles east of the town. The project is of such proportion that only a preliminary investigation could be made this year. Between the lake and the town occurs a divide, a controlling feature in limiting the height of the reservoir. This divide is 46 feet above the surface of the lake. Partial surveys show that a dam near Ashfield, 50 feet in height and 1⅝ miles long, would store 2,000,000 acre-feet or more, and would pond the water for 15 miles up Beaver Creek, a small tributary of Milk River. As this quantity far exceeded the available water supply, attention was turned to a smaller project, and the survey of a site with a flowline 25 feet above the present lake was made. The work was finished late in the season and there has not been sufficient time to complete the preliminary estimates of cost. The following table shows the capacity of this site:

Capacity of Lake Bowdoin reservoir site, Montana.

Contour.	Area.	Capacity between contours.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
2,205	4,360	0	0
2,210	9,453	34,531	34,531
2,215	12,133	53,964	88,495
2,220	13,521	64,136	152,631
2,225	14,744	70,663	223,294
2,230	15,501	75,613	298,907

A reconnaissance below Malta to Glasgow has shown that there are 107,000 acres of agricultural land available between the reservoir and Hinsdale, and 40,000 acres between this latter point and Glasgow.

MUSSELSHELL RIVER.[a]

Musselshell River, in east-central Montana, heads in the Little Belt, Elk, and Crazy mountains, and runs eastward for about 130 miles, thence turns abruptly north and continues for about 60 miles to its confluence with the Missouri. The Little Belt Mountains, north of the river, present to the Musselshell their most unfavorable side, as far as water supply is concerned, as the prevalent winds are such as to cause the snowdrifts to lie on the north side of the mountains. The sun and the chinook winds prevent the accumulation of moisture and of any considerable growth of timber on the south slopes, consequently the water supply is limited, and the streams coming into the Musselshell from the north have comparatively small floods and almost no flow in summer. The Elk Mountains are low, with little timber, and furnish little water. The northern end of the Crazy Mountains presents a condition similar to that of the Elks, the most important tributary being Cottonwood Creek, called Lost Horse Creek on the Land Office maps. This stream has a large flood discharge, but its summer flow is all needed for the bottom lands which are now under irrigation or which could be easily reclaimed in its vicinity.

Big Elk Creek presents similar conditions, and the American Fork is the largest feeder of flood waters to the Musselshell, but the lower half of this creek dries every summer, not affording a water supply for the land now under ditch.

Eastward from the American Fork, on the south and east side of the Musselshell, none of the side streams head in any mountains, and while they have considerable flood water, it soon runs off and they are left dry, except in occasional instances where there is a small supply for a short distance from springs. This is all utilized.

The main river ceases to flow each year in the vicinity of Lavina, though water stands in pools more or less to the Missouri and there is considerable underflow. This underflow might be brought to the surface by tight dams, one a few miles above Lavina and one just below Musselshell post-office, but these would supply only a small amount of water, which could be utilized only upon the bottom lands along the river, and these lands are already occupied.

There are no opportunities for the storage of the Musselshell floods to the south and any reclamation of lands between this stream and the Yellowstone would have to come from the latter stream or its tributaries.

The valley of the Musselshell lying on the north and west sides of the river is naturally divided into two parts by a high bench ridge, starting from the eastern extremity of the Big Snowy Mountains and running southeast between Willow and Flat Willow creeks to the Big Bend.

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[a] From report of S. B. Robbins.

At the base of the Little Belt and Big Snowy mountains lies a strip of bench lands, extending southward with a varying width of from 5 to 10 miles. This bench has a slope to the southeast and is cut by all the streams heading in these mountains and flowing southerly into the Musselshell. The bench is composed of gravel cemented together so hard that it would take several years of irrigation and cultivation to make farming profitable, even if water were available for it. Its elevation is about 4,000 feet at its eastern end and 5,000 feet at the western end.

Throughout this region there are some small sites for reservoirs which would irrigate a few hundred acres at most, and which can be constructed by private enterprise, as most of the land they would serve is already appropriated. The topography of the country is adverse to any large reservoirs, for the mountains are in groups with no large intermontane valleys suitable for damming, and the slope is very rapid from the mountains to the river; nor is there any place along the river itself suitable for a storage reservoir.

From the edge of this bench to the river the country is more broken—though the soil is of better character, being a sandy loam—the elevation is lower, and the bench itself is more sandy as it approaches the river.

The only practicable plan for reclamation discovered in this division is to divert the flood waters of the Musselshell in the vicinity of Winnecook, on the north side of the river, and by a canal about 10 miles long, carry them to a reservoir site locally known as Deadman Basin, thence partially by canal and partially through a natural coulée about 6 miles to the South Careless Creek reservoir. Thence the distributing canal would run northeasterly across Careless Creek (called Elk Creek on the maps), across Swimming Woman Creek, around to the northward of Folsom, crossing Cameron, Pole, and Willow creeks, and ending in the neighborhood of Lake Mason. The total length of the main canal would probably be about 70 miles. The best land begins about Folsom and extends eastward.

A small reservoir, the North Careless Creek, could be made to receive the floods of that stream and serve lands between it and Lavina, or help supply the main canal.

Deadman Basin is a natural depression cut off from the Musselshell bottoms by an encircling ridge, the lowest point of which is 41 feet above the bottom of the basin. The water level could be raised by an earth dam across this sag, having a length of about 1,000 feet, with a maximum height of 30 feet, thus giving a maximum depth of water of about 65 feet. The flooded area at this depth would be about 2,520 acres. The bottom of the basin is quite flat and the average depth of water should be at least 30 feet, which would give an approximate capacity of 75,600 acre-feet. This basin will hold water well, as the soil is a mixture of clay, sand, and a little gravel, and there are six small lakes in it, which hold water through the season.

The drainage or outlet cut would be about 5,500 feet long, of which 3,500 feet would be inside and 2,000 feet outside the reservoir. The dam across the summit would be made entirely of material excavated from this cut, and sandstone rock suitable for gateway masonry is available in the immediate vicinity of the outlet. Some rock would be encountered in the cut, though probably not much.

The South Careless Creek reservoir lies in a basin similar to Deadman, except that the bottom is flatter and the surrounding hills lower and not so rocky. Fully one-half the bed of this site is covered by a shallow lake, and the soil is an adobe clay, holding water excellently. The outlet cut would have a maximum depth of 9 feet and a total length of about 2,000 feet. The depth of water may be increased to 25 feet by a dam across the sag about 1,500 feet long. With a maximum depth of 25 feet, the flooded area would be about 2,035 acres, and the average depth of water should be at least 15 feet, thus giving an approximate capacity of 30,525 acre-feet. The flood line of this reservoir would be several feet lower than the outlet of Deadman Basin.

The North Careless Creek reservoir would occupy a basin between the hills, now containing a lake of about 180 acres, similar to the other reservoirs. In this case the maximum cut for the outlet would be 12 feet and its total length from grade to grade about 800 feet. The depth could be increased to 21 feet by a dike 1,800 feet long having a maximum height of 12 feet. The flooded area at this depth would be about 900 acres, and an average depth of 10 feet would give an approximate capacity of 9,000 acre-feet. This site will also hold water well, and can be supplied from the floods of Careless Creek, through a ditch about 4 miles long. It might be possible to carry the main canal from the South Careless Creek reservoir into the north reservoir, but the latter is probably too high. However, Careless Creek would supply water enough to fill it easily, and stored water could be turned into the main canal to aid in reclamation of lands to the east.

Definite surveys would probably result in the discovery of some additional small reservoir sites which could be utilized in connection with the lateral ditches to serve a greater area than can be done by the three main reservoirs described above.

An examination was made of Lake Mason and the smaller lakes in T. 9 N., R. 24 E., but they are not recommended for water storage, because there is a stratum of loose gravel near the surface which carries off the water. Willow Creek carries a small stream of water into Lake Mason, varying in size according to the amount of irrigation above the lake along the creek, but except during the flood season no water runs out of the lake.

A well near the edge of the outlet creek and about a mile below the lake is 6 feet deep and 4 feet in diameter, holding 3 feet of water. The upper stratum contains some sand and clay for 3½ feet, then comes a foot of hardpan, and then loose water-bearing gravel. After being bailed out the water resumed its natural level in four or five hours.

Around the edge of this basin lie some 15,000 acres of the best lands in this division, having good soil and a gentle slope toward the lakes. In addition to the fact that the lake will not hold water well, the country is too flat to allow more than 10 or 15 feet of water to be stored. Also, there is little land below this lake suitable for agriculture until the valley of Flat Willow Creek is reached. Most of the intervening land which is low enough is badly cut up by coulées and is rough and rolling. However, careful surveys may develop the fact that a lateral might be constructed from this lake to utilize the natural drainage into it and the seepage from the irrigation of surrounding lands when reclaimed by the proposed Musselshell Canal. This lateral might serve a small area between Willow and Pole creeks, near Roundup.

None of the country to the north of the Big Bend can be served from the Musselshell, as there is no opportunity to store the water.

The floods of the Middle Musselshell could be diverted from the river in the vicinity of Roundup and carried along on the south side in a northeasterly direction and thrown across the divide into the Big Dry Creek country, if storage capacity can be found in that vicinity, and if the land and topography are suitable for irrigation.

The country west of the Musselshell and north of Flat Willow presents conditions quite similar to the south division, except that the general elevation is less and the lower portions of all the streams run through bad lands, growing more broken and extending farther back from the Musselshell as the Missouri River is approached. Along the latter stream these bad lands extend for a long distance both east and west from the mouth of the Musselshell.

The unsurveyed Ts. 17 to 20 N., Rs. 26 to 30 E., inclusive, are rough and unsuited for any reclamation plan other than very small storage reservoirs, which can easily be put in by private enterprise.

Ts. 17 to 19 N., Rs. 22 to 25 E., inclusive, are fair agricultural land, but contain no storage sites beyond the capabilities of modest private capital.

There were two reservoir sites found which would reclaim considerable good land if utilized, viz, Wild Horse and Warhouse Butte lakes, the former being much the better.

Wild Horse Lake lies in a depression on the bench between Ford and Big Box Elder creeks, and could be filled from the floods of these streams.

The maximum cut to drain this basin would be 35 feet, and the outlet canal would be 2,100 feet long on the inside of this ridge and 1,400 feet long to grade on the outside. An earth fill of 15 feet maximum height and 1,000 feet in length would have to be built across a sag where the inlet canal from Box Elder Creek would enter. Also a fill of the same height and 1,100 feet long would be needed across the outlet sag. These would give a maximum depth of water in the reservoir of nearly 50 feet, and could be raised higher if found desirable, according to the water supply found available and the exact area of land reclaimable upon detailed surveys being made. The flooded area at this depth would be approximately 5,380 acres, and with an average depth of water of 20 feet the storage capacity would be 107,600 acre-feet.

Good quality of sandstone is available within 1½ miles of the outlet.

The soil at both of these sites is particularly well adapted for water storage and there seems to be almost no seepage.

There was no opportunity to establish gaging stations at suitable points on either Box Elder or Ford creeks because of lack of inhabitants to act as attendants. The flood cross section of Box Elder a little below the point where Ford Creek empties in is about 400 square feet, and the current must be swift, as the fall to both creeks is considerable. There is little doubt of there being sufficient water available in floods to fill the reservoir.

There is no permanent flow in either creek, except near their sources, and they go dry early in the season at the points where the inlet canals to the reservoir would leave them. These canals would be about 7 miles long each.

If the water of Ford Creek was not needed for Wild Horse Lake it could be turned into Warhouse Butte Lake by a canal about 7 miles long. Another source of supply for the latter reservoir would be McDonald Creek, which could be diverted at about its forks, near Grass Range, where there is a small permanent flow, and carried across the divide about 15 miles to this lake.

This reservoir would also need two earth fills in order to store a large body of water. One would be near the inlet, and would be 2,400 feet long and have 14 feet maximum height. The second would be across the outlet sag, and would be 1,600 feet long and 18 feet maximum height. These fills could not be raised much without adding very considerably to their length, more particularly in the case of the first one.

The maximum cut for the outlet would be 3 feet, and length of outlet canal, grade to grade, 2,500 feet.

With a maximum depth of 18 feet of water the flooded area would be approximately 1,420 acres, and with 9 feet average depth of water the capacity would be 12,780 acre-feet.

The irrigable lands would begin immediately below the outlets of both reservoirs and would extend on both sides down Box Elder.

The better land and the most favorable topography is to the west of this stream, there being good land along Buffalo Creek just south of Warhouse Butte reservoir, and some good bottoms along McDonald and Flat Willow creeks and a good bench between these creeks.

These two reservoirs would work in well together in forming a single system.

The country north of the Big Bend of the Musselshell and on the east side of the river which is tributary to this stream is entirely unsuited to irrigation and impracticable to reclaim, as it is very rough, rolling, and broken into bad lands, much of which is impassable even to a person on horseback.

NEBRASKA.

In Nebraska the conditions are somewhat similar to those in Kansas. There is a relatively small amount of land in Government ownership which can be reclaimed. The lands that can be reached by water from ordinary sources have been taken up by prospective settlers. The area of public land is, however, considerably larger than in Kansas, as the State extends farther west, into more arid regions. There are, in round numbers, 10,000,000 acres of arid public lands, and the disposal of these will make available a considerable amount of money which can be utilized in irrigation works. The area irrigated in Nebraska in 1899 was 148,538, a notable increase since 1889, when the acreage irrigated was only 11,744 acres. The lands watered are mainly along North Platte River in the extreme western part of the State, although irrigation is practiced widely from wells, water being lifted by windmills or various forms of machinery driven by steam or gasoline.

The general examination of artesian conditions has been extended across Nebraska, and it is believed that a few deep wells can be sunk to advantage, demonstrating whether water will rise to the surface in sufficient quantity and of such quality as to be used for irrigation. Some of the flowing wells of the State carry so large an amount of mineral water in solution that this can not be successfully applied to crops; hence it is a question not merely of obtaining flowing water but of getting wells whose water is sufficiently good for industrial purposes.

The most complete development of irrigation in a large way is probably that by which waters of North Platte River may be taken out upon the level lands adjacent to the river. To reach the best lands it may be necessary that the canals head in Wyoming. In any event, the complete utilization of North Platte River will require the construction of reservoirs near the headwaters. Thus, it is essential to study the North Platte as a whole, in order to determine how to most completely save the waters and put them to the most beneficial use, both in Wyoming and in Nebraska. For this purpose examination of the river has been begun, as described later under "Wyoming."

Unappropriated, reserved, and appropriated lands in Nebraska on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Adams	4, 021		363, 339	367, 360
Antelope	11, 360		548, 000	559, 360
Banner	55, 329	1, 800	419, 031	476, 160
Blaine	246, 118		208, 922	455, 040
Boone			439, 040	439, 040
Boxbutte	58, 752		631, 168	689, 920
Boyd	34, 681		320, 519	355, 200
Brown	445, 334		337, 386	782, 720
Buffalo	400		630, 000	630, 400
Burt	5, 640		299, 000	304, 640
Butler			375, 040	375, 040
Cass			345, 600	345, 600
Cedar			464, 000	464, 000
Chase	56, 280		520, 360	576, 640
Cherry	2, 484, 494	35, 000	1, 250, 746	3, 770, 240
Cheyenne	502, 550	1, 040	1, 161, 050	2, 664, 640
Clay	6, 040		369, 000	375, 040
Colfax	3, 200		256, 000	259, 200
Cuming	3, 200		368, 000	371, 200
Custer	54, 712		1, 606, 088	1, 660, 800
Dakota	14, 960		154, 000	168, 960
Dawes	177, 310	8, 110	717, 620	903, 040
Dawson	5, 500		635, 780	641, 280
Deuel	654, 598		687, 482	1, 342, 080
Dixon			288, 000	288, 000
Dodge			338, 560	338, 560
Douglas	6, 240		212, 000	218, 240
Dundy	123, 960		465, 480	589, 440
Fillmore			363, 520	363, 520
Franklin			363, 520	363, 520
Frontier	8, 880		618, 320	627, 200
Furnas			457, 600	457, 600
Gage			547, 840	547, 840
Garfield	155, 159		208, 361	363, 520
Gosper	3, 080		299, 000	302, 080
Grant	335, 965		150, 435	486, 400
Greeley	8, 452		362, 748	371, 200
Hall	15, 680		344, 000	359, 680
Hamilton			352, 000	352, 000
Harlan			359, 680	359, 680

Unappropriated, reserved, and appropriated lands in Nebraska on June 30, 1901—Cont'd.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Hayes	25,240		438,760	464,000
Hitchcock	7,440		455,280	462,720
Holt	113,697		1,428,703	1,542,400
Hooker	343,612		120,388	464,000
Howard	1,360		366,000	367,360
Jefferson			362,240	362,240
Johnson	5,480		239,000	244,480
Kearney			321,920	321,920
Keith	157,602		554,718	712,320
Keyapaha			494,080	494,080
Kimball	117,531		496,869	614,400
Knox	9,480		710,520	720,000
Lancaster	6,520		549,000	555,520
Lincoln	206,271		1,438,529	1,644,800
Logan	182,183		186,457	368,640
Loup	206,500		160,860	367,360
McPherson	847,690		230,710	1,078,400
Madison	2,640		366,000	368,640
Merrick			294,400	294,400
Nance	3,840		288,000	291,840
Nemaha	13,480		247,000	260,480
Nuckolls			366,080	366,080
Otoe	3,240		391,000	394,240
Pawnee	3,680		276,000	279,680
Perkins	12,880		559,920	572,800
Phelps	16,960		344,000	360,960
Pierce			363,520	363,520
Platte	1,360		437,680	439,040
Polk			276,480	276,480
Redwillow	3,200		457,600	460,800
Richardson	11,720		339,000	350,720
Rock	236,454		403,546	640,000
Saline			368,640	368,640
Sarpy	3,000		141,000	144,000
Saunders	1,960		487,000	488,960
Scotts Bluff	159,694		304,306	464,000
Seward	10,320		366,000	376,320
Sheridan	412,771	12,534	969,255	1,394,560
Sherman			363,520	363,520
Sioux	906,652	11,158	411,470	1,329,280

Unappropriated, reserved, and appropriated lands in Nebraska on June 30, 1901—Cont'd.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Stanton	1,840		274,000	275,840
Thayer			366,080	366,080
Thomas	344,552		116,248	560,800
Thurston	8,440		245,000	253,440
Valley	3,808		366,112	369,920
Washington	14,880		236,000	250,880
Wayne			282,240	282,240
Webster	3,920		366,000	369,920
Wheeler	99,368		273,112	372,480
York	10,320		366,000	376,320
	10,003,480	69,642	39,104,478	49,177,600

The above shows the condition on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office will be found on page 19.

NEVADA.

The needs of reclamation in this State are conspicuously great, but the available funds are almost insignificant. This arises from the fact that under a law especially applicable to Nevada selections have been made of most of the lands which control the water and consequently the opportunities for settlement. Thus although the Government still owns by far the greater part of the State, this vacant land is not being disposed of and few demands are being made for Government land.

The situation in Nevada is further complicated by the fact that much of its water supply comes from across the State line on the west. The high mountains which separate Nevada from California have been included largely in the latter State, the boundary between these States being drawn diagonally across the foothills. Thus to utilize the spring floods it will be necessary to construct reservoirs in California and take the waters out upon lands in Nevada.

Another complication as regards reclamation arises from the fact that the grant of alternate sections along the line of the Central Pacific Railroad covers all of the valley lands extending along Humboldt River. A considerable portion of these railroad lands and of the adjacent Government sections has passed into the control of cattlemen, and the waters of Humboldt River are used mainly for flooding meadows and for raising wild hay.

The following table gives by counties the area of vacant land, the amount reserved, appropriated, and the total area on June 30, 1901.

A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office will be found on page 19.

Unappropriated, reserved, and appropriated lands in Nevada on June 30, 1901.

County.	Area unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Churchill	2,577,679	420,356	84,205	3,082,240
Douglas	297,485	....	264,435	561,920
Elko	8,204,847	1,800,867	835,246	10,840,960
Esmeralda	5,291,637	259,200	65,803	5,616,640
Eureka	2,181,815	371,528	77,697	2,631,040
Humboldt	8,075,481	1,792,891	452,268	10,320,640
Lander	2,960,224	336,577	99,679	3,396,480
Lincoln	12,065,068	1,427	373,185	12,439,680
Lyon	511,885	190,516	108,479	810,880
Nye	11,002,555	....	118,085	11,120,640
Ormsby	2,752	1,920	72,128	76,800
Storey	72,434	91,163	4,723	168,320
Washoe	2,529,242	716,964	345,474	3,591,680
White Pine	5,446,081	....	129,599	5,575,680
Total	61,219,185	5,983,409	3,031,006	70,233,600

There are throughout the State a considerable number of small streams flowing from the isolated mountain masses. The lands along these streams or around the springs have been selected by the State and disposed of to cattlemen; the ownership of a few hundred acres which include the water thus gives control of thousands of acres of vacant public lands, since this land is worthless except in connection with the use of the springs. Settlement and irrigation development have thus been greatly retarded and progress toward reclamation impeded by the private rights attached to the isolated sources of water supply.

The total area irrigated in Nevada in 1899 was 504,168 acres. Ten years earlier only 224,403 acres were irrigated. Most of this land consists of meadow lands overflowed during the spring by the waters of Humboldt River, the floods being guided and directed by comparatively cheap methods, so that it is difficult to distinguish between the lands naturally watered and those artificially watered. The crops irrigated are mainly wild hay and alfalfa, there being a small acreage of wheat, barley, oats, potatoes, and orchards. The most thoroughly cultivated areas are those on the western side of the State, along Truckee and Carson rivers and near the cities of Reno and Carson.

The streams of most importance in the irrigation development of the State are the Humboldt and those issuing from the Sierra Nevada, the principal of these being the Truckee, Carson, and Walker. The summer flow of these streams is largely employed, and reclamation of any considerable area of desert land at the foot of the mountains is dependent upon water storage. This fact has been long recognized, and in 1889 the Powell Irrigation Survey began systematic examinations, but the work was not brought to a conclusion. At a later date Hon. Francis G. Newlands, on behalf of the Sharon estate, had extensive

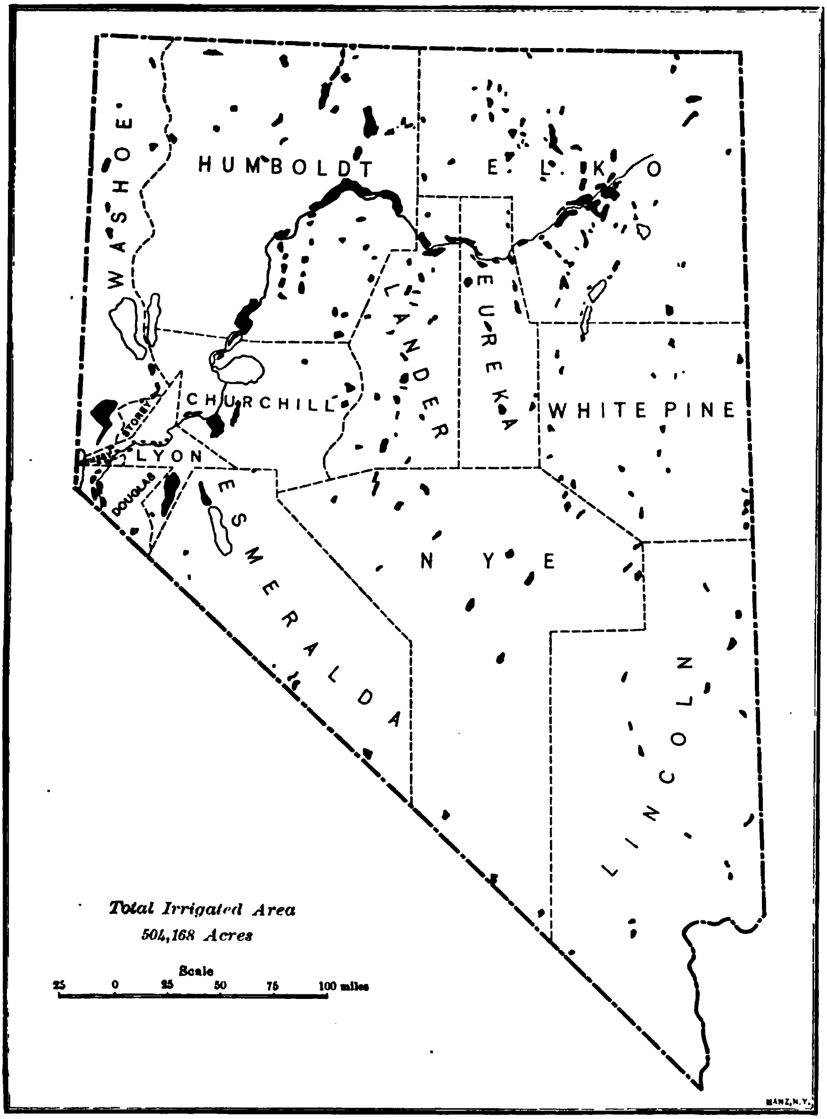

FIG. 38.—Map of irrigated areas in Nevada.

surveys made and published a report dealing with the opportunities for reclamation. Systematic measurements of river flow have been maintained for a number of years, and in 1899 Mr. L. H. Taylor examined a number of reservoir sites, the work being continued in later years. On the passage of the reclamation law Mr. Taylor's work was extended,

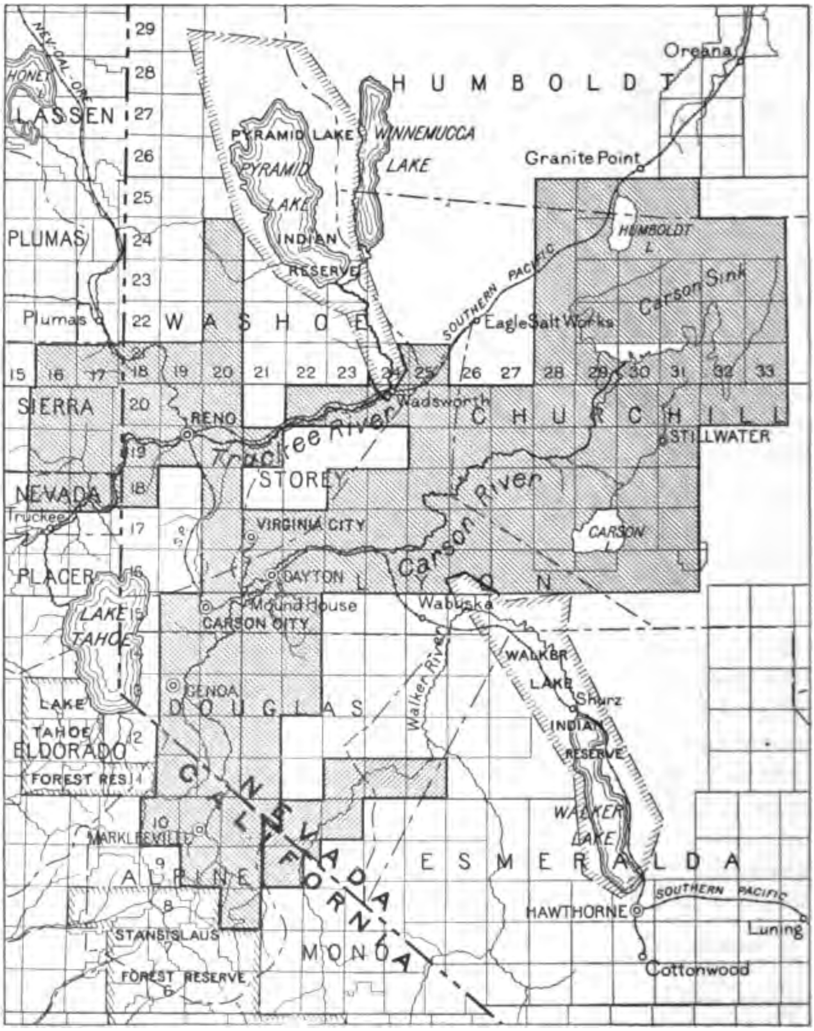

FIG. 39.—Map of lands segregated in Nevada.

and a number of important localities were surveyed during the summer of 1902. The principal items of this work are as follows:

(1) General reconnaissance of Walker River, by L. H. Taylor and D. W. Hays, laying out preliminary work of surveying reservoir sites and canal lines.

(2) Preliminary platting of Walker River Basin and subdivisions on scale one-fourth inch and 1 inch to mile, by D. W. Hays.

(3) Preliminary survey of Leavett Meadows reservoir and dam site, on West Walker River, Mono County, Cal., with transit and stadia.

(4) Preliminary survey with transit and stadia of Twin Lakes reservoir and dam site, on Robinson Creek, a tributary of Walker River, Mono County, Cal.

(5) Preliminary survey of Big Meadows reservoir site, on East Walker River, below Bridgeport, Mono County, Cal., with transit and stadia.

(6) Preliminary survey for canal from East Walker River, to command about 20,000 acres of land to the south of Mason Valley in Ts. 10 and 11 N., Rs. 25 and 26 E., Mount Diablo meridian. This survey started south of Mason Valley from a pass, through which canal must run to reach the land to be irrigated, and ran upstream southward on grade of 1 in 3,000 for a distance of 100,000 feet. Demonstrated impracticable and abandoned.

(7) Preliminary survey of canal line from West Walker River, about 6½ miles, to command about 7,000 acres of land in the southern part of Mason Valley, between East and West Walker rivers.

(8) Preliminary survey of canal line from Walker River in left bank below junction of East and West forks, run along west side of Mason Valley 7 miles to a pass in low hills west of Yerington, where it will command approximately 30,000 acres of land in the northwest part of Mason Valley.

(9) Preliminary survey for canal line from East Walker River where same enters Mason Valley, along east side of said valley a distance of 140,000 feet, to command about 50,000 acres of land to the east of Walker River in Mason Valley.

(10) Preliminary survey for canal line from west side of West Walker River in Antelope Valley, below Coleville, along west side of valley and through low hills bordering Alkali Lake on northeast, to command about 6,000 acres of land in northwest and northern part of Antelope Valley, this land being partly in California and partly in Nevada.

(11) Preliminary survey for canal line from east bank of West Walker River near south end of Antelope Valley, running northerly along east side of valley a distance of 80,000 feet, to command about 18,000 to 20,000 acres of land in that valley lying eastward of the river.

(12) Survey with transit and stadia of Alkali Lake reservoir site.

(13) Preliminary survey for canal line from Carson River above Dayton, Nev., along base of mountains to north of Carson River, to supply Alkali Flat reservoir, a distance of 92,000 feet. This canal will also command about 8,000 acres of land, while an extension of same from the mountain ridge where it drops to reservoir, 7 miles, will command an additional 4,000 acres.

(14) Preliminary survey for canal line heading in right bank of Carson River a short distance above Dayton, Nev., and running along foothills south of river, a distance of 8 miles, commanding about 3,500 acres of land to the east of the town of Dayton.

(15) Survey with transit and stadia of Alkali Flat reservoir site about 12 miles east of Dayton and to the north of Carson River.

(16) Survey and plotting with plane-table Lower Carson reservoir site, situated on Carson River at point where river enters Carson Sink Valley.

(17) Surveying and plotting on scale of 100 feet to 1 inch, with 5-foot contours, to 25 feet above and below grade line, Truckee River Highline canal, from Truckee River at Floriston, Cal., to command about 75,000 acres of land to north and northeast of town of Reno. About 25 miles completed.

(18) Survey of branch from main canal above described around east side of Lemons Valley, to reach lands in Hungry and Warm Springs valleys. Surveys begun October 1; about 30 miles completed.

(19) Survey of branch from main canal above described around west side of Lemons Valley, to command said valley. Same methods as above. Commenced October 24; 6 miles completed.

TRUCKEE RIVER STORAGE AND DIVERSION.[a]

Truckee River has its collecting basin on the eastern slope of the high Sierra Nevada in California (see fig. 40), embracing a forest-clad region, in elevation from 5,000 to 11,000 feet above sea level, on which the precipitation, mainly in the form of snow, is heavy. Upper Truckee River has a general northerly course, and flows into Lake Tahoe, which has an elevation of 6,225 feet above sea level and an area of 193 square miles. From the outlet of the lake the river continues in a northerly direction, for a short distance, receiving a number of important tributaries, after which it turns eastward. After passing Verdi the river, entering what has been called the lower portion of the Truckee River Basin, continues eastward for a distance of 45 miles, passing through Reno Valley and Lower Truckee Canyon to Wadsworth, whence it turns northward, flowing about 20 miles farther and discharging into Pyramid and Winnemucca lakes.

EARLY INVESTIGATIONS.

The basin was early recognized as one in which irrigation development would be extensive, as possibilities for the construction of numerous storage reservoirs existed in the mountainous area. It was one of the sections investigated by the Powell Irrigation Survey in 1889–90. A number of gaging stations were established at that time, and discharge measurements were maintained for several years. Measurements were discontinued in 1892, but several stations were resumed in 1899, and their number has been gradually increased, so that at the present time considerable information in regard to the water supply is available. For information regarding the early work in this division reference should be made to the Eleventh, Twelfth, and Thirteenth Annual Reports of the Geological Survey, wherein is described the possible utilization of Tahoe, Donner, Independence, and Webber lakes as storage reservoirs, besides the surveys of other sites, and the mode of diverting and employing the waters thus obtained. In the Twentieth Annual Report, Part IV, pages 29 to 36, is given a list of the sites surveyed during the early investigations, also reference to the volumes and pages of the reports which contain more detailed information, as well as some of the general facts regarding each site.

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[a] From report of L. H. Taylor.

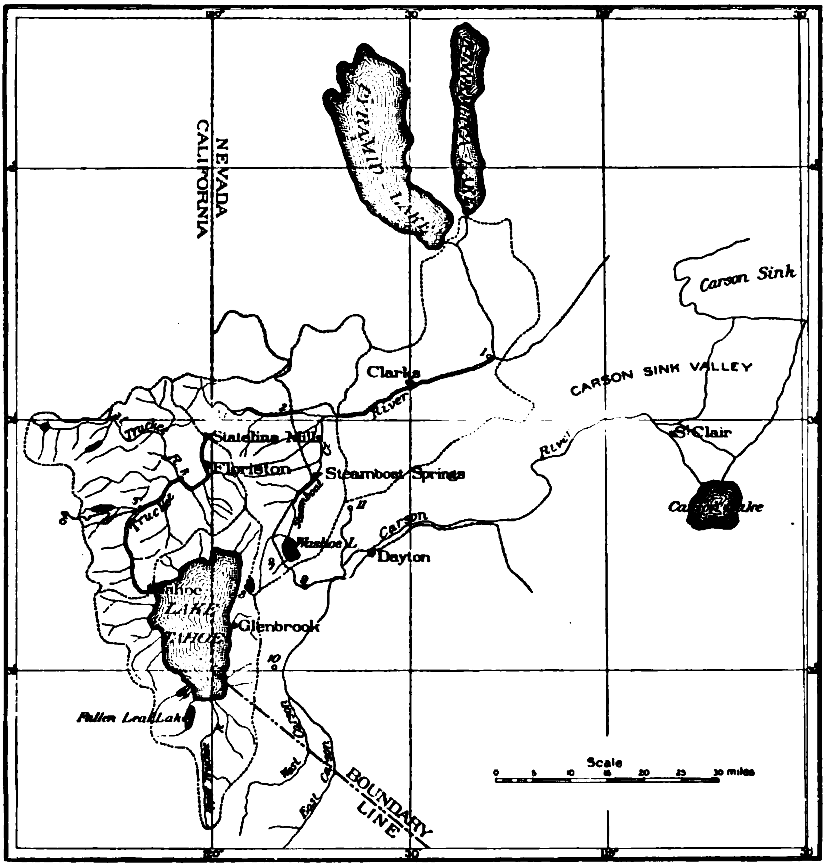

FIG. 40.—Map of Truckee River Basin.

A general study of the various reservoir sites known to exist within the Truckee Basin was begun in 1900, by Mr. L. H. Taylor, with a view to ascertaining the volume of the run-off from the drainage area tributary to each and the extent to which it might economically be impounded. The information derived from the earlier surveys was supplemented by the field work necessary to develop the facts and estimates briefly stated on the following pages. The detailed report is printed in Water-Supply Paper No. 68.

EVAPORATION.

In addition to the surveys observations were undertaken of the amount of evaporation from free water surfaces. On May 17, 1900, a galvanized-iron tank was placed in Lake Tahoe, at its outlet, and observations were continued from that date until the end of December of the following year. The following table gives the results:

Evaporation of Lake Tahoe at Tahoe, Cal., from May 17, 1900, to December 31, 1901.

[Elevation, 6,225 feet.]

Month.	1900.	1901.	Month.	1900.	1901.
	Inches.	*Inches.*		*Inches.*	*Inches.*
January		0.84	July	4.00	([a])
February		.70	August	5.15	6.50
March		.77	September	3.10	4.12
April		1.25	October	2.15	2.65
May 17 to 31	1.83	2.42	November	1.38	2.09
June	3.80	3.35	December	1.33	1.44

[a] No record.

During the year 1894 Mr. Taylor conducted a series of observations of evaporation at Reno, Nev. A small galvanized-iron tank, 18 inches square and 18 inches deep, was sunk in the ground and was kept filled to within 1 inch of the top, being placed so as to be fully exposed to sun and wind. The earth immediately around the tank was kept wet. The following table gives the results of these measurements:

Evaporation from tank in earth at Reno, Nev.

[Elevation, 4,499 feet.]

	Inches.
May 11 to 31	2.80
June	5.35
July	8.45
August	9.12
September	7.44
October	4.31
November	2.75
Total	40.22

If the evaporation during the remaining five months of the year amounts to 12.78 inches, or an average of about 2½ inches a month, which would appear from the foregoing table to be a fair estimate, the total for the year would be 53 inches.

LAKE TAHOE.

By the construction of a relatively low dam at the outlet of this lake (see figs. 41 and 42) an immense body of water, 745,400 acre-feet, can

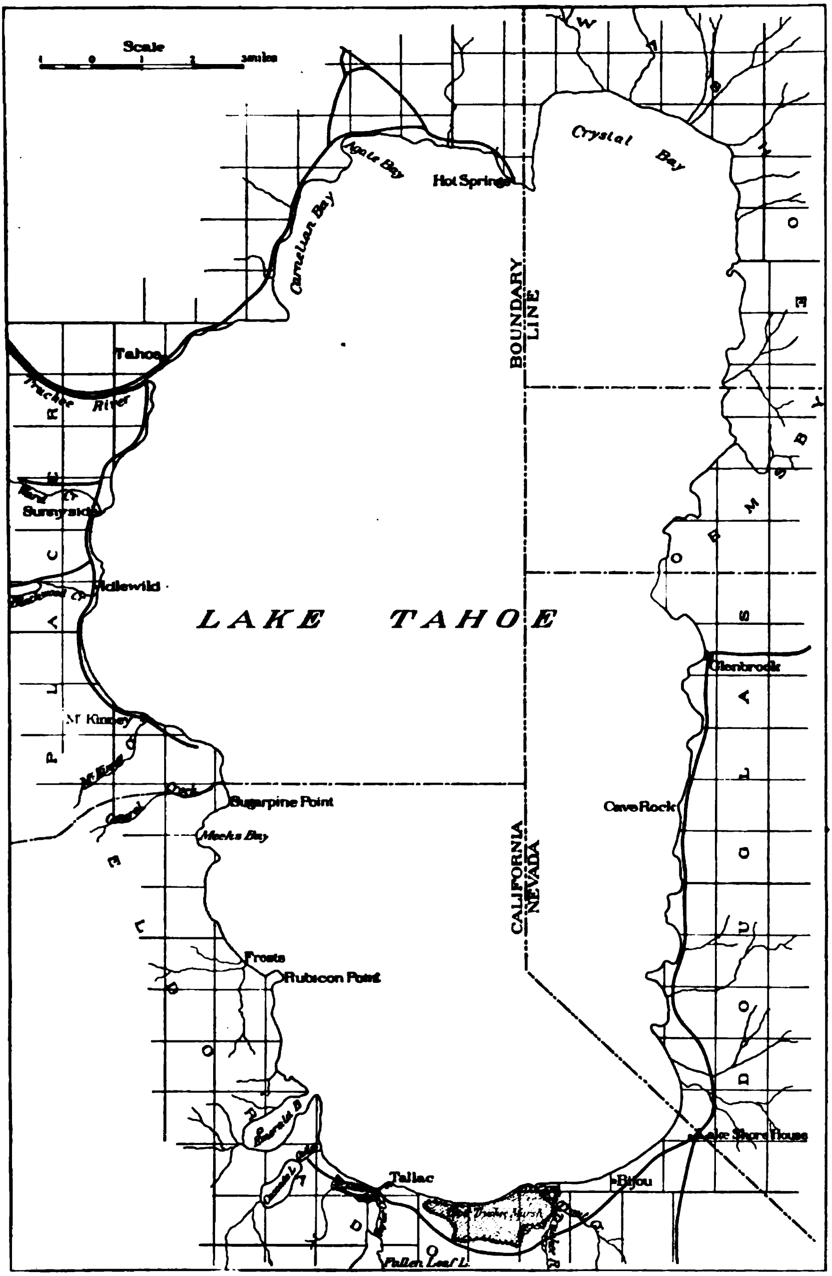

Fig. 41.—Map of Lake Tahoe.

be stored. The site selected as the most favorable for the location of a permanent dam is near a private dam now in the channel of the river. Here, at about the level of the lowest part of the river bed and extending across the channel, is a firm conglomerate or indurated gravel, which will afford a very good foundation. It is planned to erect on this a concrete dam having a maximum height of 13 feet and a top length of 220 feet. In this structure will be 25 openings, each 4 feet wide and 6 feet high. These openings will be closed by iron-bound flashboards, and the supply from the lake will be regulated by the removal of one or more flashboards from each of the openings. No wasteway will be required, as the surplus water can at all times be drawn off through the openings or can safely pass over the dam. By raising the level of the lake to the proposed height considerable areas of low, marshy ground will be inundated at various points. The minimum run-off from the basin is placed at 200,000 acre-feet. The following is the estimate of cost:

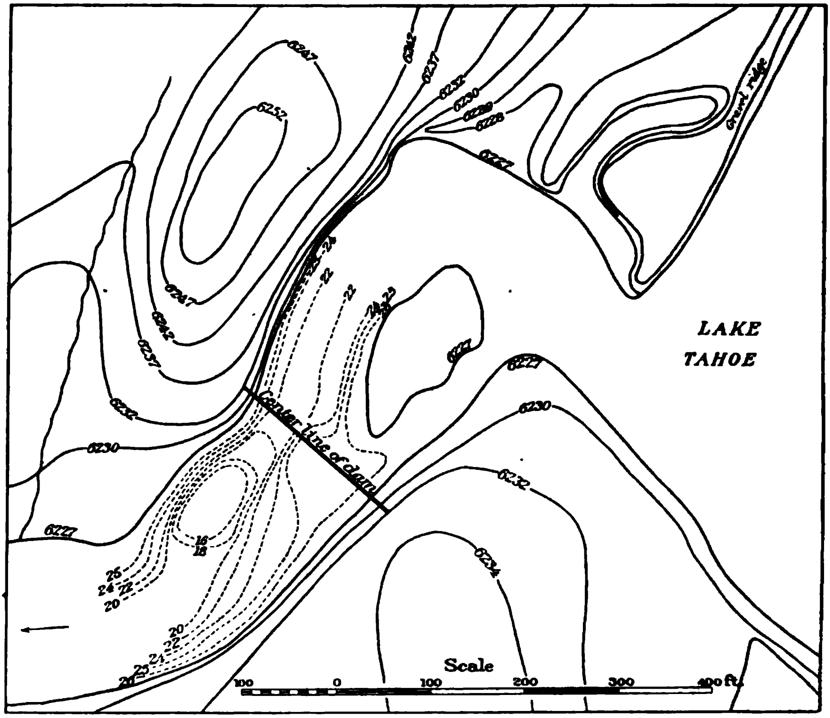

FIG. 42.—Contour plan of Lake Tahoe dam.

Estimate of cost of proposed Lake Tahoe reservoir.

Dam:

680 cubic yards of concrete, at $10	$6,800
Footbridge, 200 feet, at $2.50	500
Cofferdam for foundation	500
Excavation for foundation, 700 cubic yards, at $1	700
Iron-bound flashboards, 200, at $2.50	500

Deepening channel from lake to dam, distance 500 feet, excavation 5,000 cubic yards, at $0.60		$3,000
Deepening channel below dam for 2,000 feet, bed width 100 feet, excavation 10,000 cubic yards, at $0.20		2,000
Damages for land flooded:		
Upper Truckee marsh, 1,240 acres, at $4	$4,960	
Taylor Creek marsh, 110 acres, at $5	550	
Grounds at Tallac	1,250	
At Tahoe City, 7½ acres, at $100	750	
		7,510
For engineering		5,000
Legal expenses		3,000
Contingencies, 10 per cent		2,951
		32,461

DONNER LAKE RESERVOIR.

Donner Lake occupies a glacial basin lying close under the crest of the main Sierra Nevada and lengthwise between two eastward projecting spurs. Its ordinary water surface is nearly 3 miles long, with a nearly uniform width of approximately a half mile, and is about 6,095 feet above sea level. (See fig. 43.) The project for the utilization of this basin for a reservoir contemplates the construction of a long, low dam following the location of the ancient terminal moraine, nearly half a mile from the lower end of the lake, and impounding not only the surplus waters of the Donner Lake watershed but those of the Cold Creek drainage basin also, by leading them into the reservoir by means of a canal about 3,000 feet in length. The drainage area of Donner Lake above the dam site is 14 square miles, while that of Cold Creek above the reservoir is 13.5 square miles.

Continuous records of the run-off from this watershed have not been

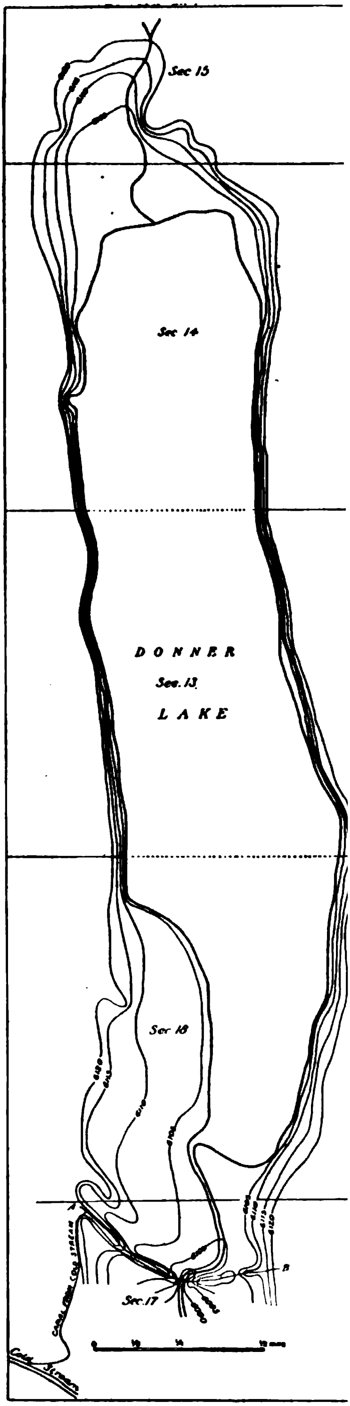

Fig. 43.—Contour map of Donner Lake.

kept, but numerous measurements of the flow of both Donner and Cold creeks have been made from time to time. From a study of these measurements, together with the precipitation records, it is believed that the average annual yield of the basin is over 26,900 acre-feet. As planned, the dam will be of earth, with a top length of 2,630 feet and a maximum height of 38.5 feet in the narrow gap through which flows Donner Creek. The inner face will have a slope of 3 to 1 and the outer face a slope of 2 to 1, the inner slope to be paved with broken stone.

The following table gives the area and capacity of the reservoir for each 10 feet in elevation:

Area and capacity of proposed Donner Lake reservoir.

Contour.	Area.	Contents.
Feet.	*Acres.*	*Acre-feet.*
6,095	840	0
6,105	980	9,100
6,110	1,140	14,400
6,115	1,260	20,400
6,120	1,340	26,900

By the construction of the dam some private lands will be flooded, for which an estimate of the damages has been included in the following estimate of cost:

Estimate of cost of proposed Donner Lake reservoir.

Dam:		
Earth embankment, 134,000 cubic yards, at $0.25		$33,500
Foundation		2,000
Riprap revetment, 14,400 square yards, at $0.65		9,360
Outlet works:		
400 feet 36-inch cast-iron pipe, at $8.75 laid	$3,500	
200 cubic yards of concrete incasing pipe, at $8	1,600	
Valves, gates, and hoist	1,400	
		6,500
Wasteway		2,000
Supply canal from Cold Creek		1,500
Damages to lands and improvements		20,000
Engineering		4,000
Contingencies, 10 per cent		7,886
Total		86,746

Cost per acre-foot of storage, $3.25.

INDEPENDENCE LAKE RESERVOIR.

Independence Lake (see map, fig. 44) is almost an exact counterpart of Donner Lake. It is of glacial origin, lies immediately under the crest of the Sierra Nevada, and is held lengthwise between high, precipitous spurs projecting at right angles from the main range. Its ordinary water surface is about 2½ miles in length and somewhat less than a half mile in width, and covers an area of 709 acres. The annual yield from the basin is estimated at 14,500 acre-feet.

It is planned to construct at a suitable site a dam having a maximum height of 10 feet above ordinary low water, ultimately drawing it down to a depth of 5 feet below the same plane. The maximum height of this structure will be 27 feet, the top length 960 feet. It is designed to have a dam similar to the one planned for Donner Lake—that is, of earth construction. The following table gives the area and capacity of the proposed reservoir at various elevations:

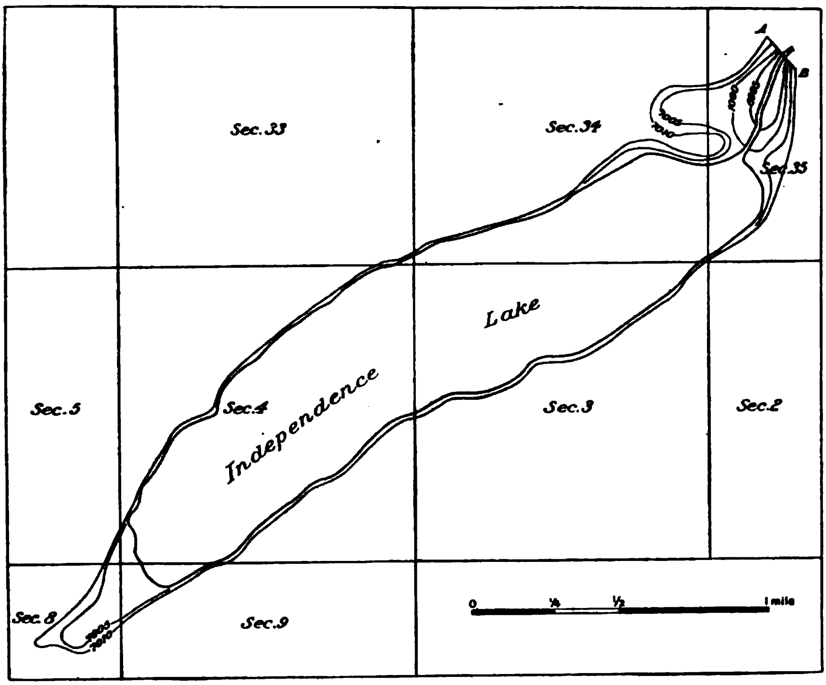

Fig. 44.—Contour map of Independence Lake.

Area and capacity of proposed Independence Lake reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
6,995	700	0
7,000	740	3,600
7,005	820	7,500
7,010	870	11,725

Only about 160 acres of land, all in private ownership, would be flooded by this reservoir. The following is the estimate of cost:

Estimate of cost of proposed Independence Lake reservoir.

Dam:		
Earth embankment, 25,600 cubic yards, at $0.25		$6,400
Foundation		1,000
Riprap revetment, 3,600 square yards, at $0.75		2,700
Outlet works:		
Excavating channel to drain lake to depth of 5 feet, 5,000 cubic yards, at $0.20	$1,000	
300 feet of 30-inch cast-iron pipe, at $8, laid	2,400	
140 cubic yards of concrete incasing pipe, at $8.50	1,190	
Valves, gates, and hoist	1,200	
		5,790
Wasteway, complete		1,000
Damage to land and summer resort		12,000
Engineering		2,000
Contingencies, 10 per cent		3,089
Total		33,979

Cost per acre-foot of storage, $2.898.

WEBBER LAKE RESERVOIR.

Six miles northwest of Independence Lake, at an elevation of 6,765 feet above sea level, lies Webber Lake, bounded on the south by a flat, grass-covered meadow. A contour map of the lake and a profile of the dam site are shown in fig. 45. The lake is nearly round, and covers an area of 233 acres. The annual yield from the basin is placed at 23,893 acre-feet. The dam is similar to the one proposed for Donner Lake, and has the same arrangement of outlet works. It would have a maximum height of 35 feet and a top length of 950 feet. The following table gives the area and capacity of the proposed reservoir at various elevations:

Area and capacity of proposed Webber Lake reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
6,765	237	0
6,770	395	1,580
6,775	535	3,905
6,780	653	6,875
6,785	777	10,450

By the construction of this reservoir about 540 acres of land, mostly in private ownership, would be flooded, and an attractive summer resort on the north shore of the lake would be destroyed. For this reason and because of the fact that the same water can be more economically stored at other points, further consideration of this reservoir site has been abandoned.

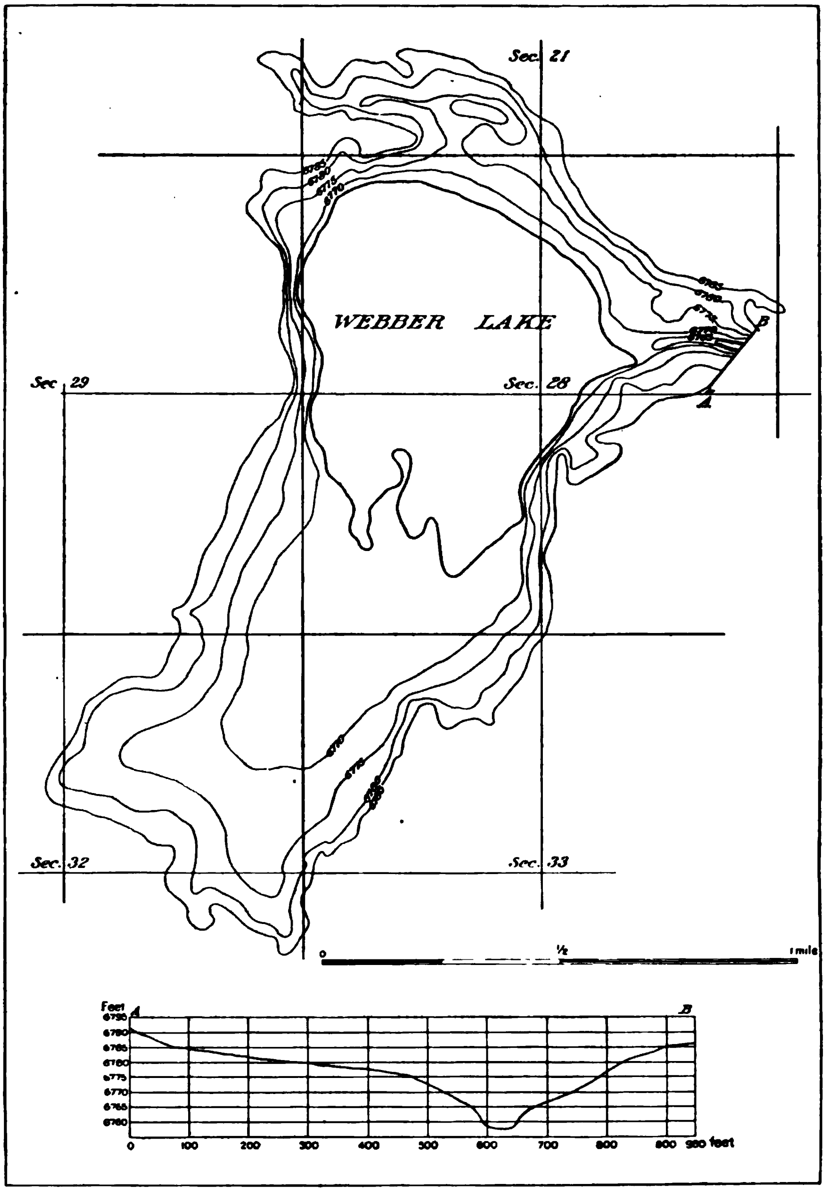

FIG. 45.—Contour map of Webber Lake and profile of dam site.

SQUAW VALLEY RESERVOIR.

This reservoir site occupies a small glacial basin on Squaw Creek, a tributary of Truckee River from the west, about halfway between Lake Tahoe and Truckee. As planned, the dam will have a maximum height of 22.5 feet and a top length of 480 feet. From preliminary surveys the capacity of the reservoir is placed at 1,600 acre-feet. Continuous records of the discharge of Squaw Creek have not been kept, but from a number of miscellaneous measurements it is believed that the annual run-off from the basin is more than sufficient to fill the reservoir. Owing to its small capacity and the consequent relative high cost of maintenance and operation, this site has not been deemed worthy of incorporation in the general plan for water storage in Truckee River Basin.

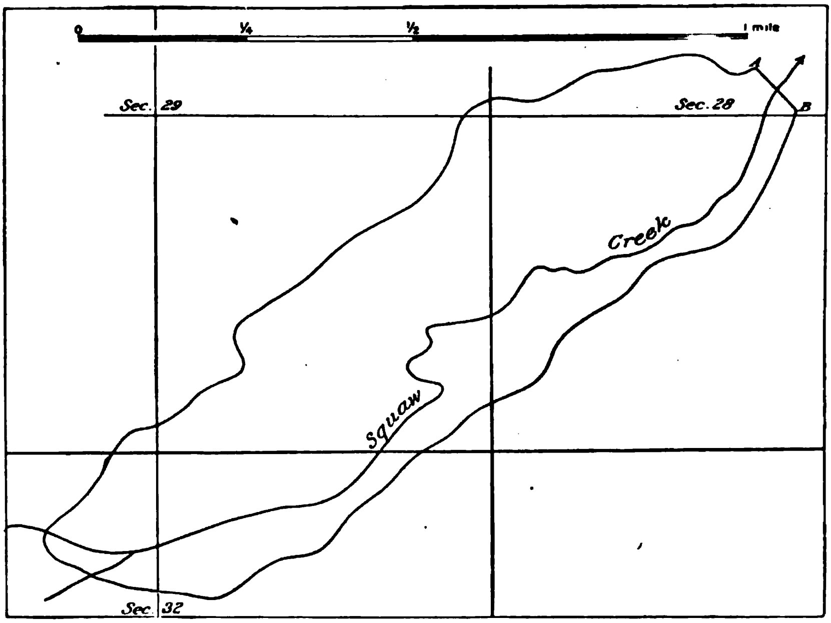

FIG. 46.—Contour map of Squaw Valley reservoir site.

TWIN VALLEY RESERVOIR.

This reservoir is on the North Fork of Prosser Creek, one of the main branches of Truckee River, at an approximate altitude of 6,300 feet above sea level. The drainage area above the site is 12 square miles. No measurements of discharge of this branch of Prosser Creek have been made, but from a study of the run-off tables of adjoining basins it is believed that the annual yield will exceed the capacity of the reservoir, which is approximately 7,818 acre-feet.

Area and capacity of Twin Valley reservoir site at different elevations.

Contour.	Area.	Capacity.	Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*	*Feet.*	*Acres.*	*Acre-feet.*
6,305	3	0	6,330	221	2,105
6,310	23	65	6,335	266	3,323
6,315	50	248	6,340	292	4,718
6,320	85	585	6,350	328	7,818
6,325	151	1,175			

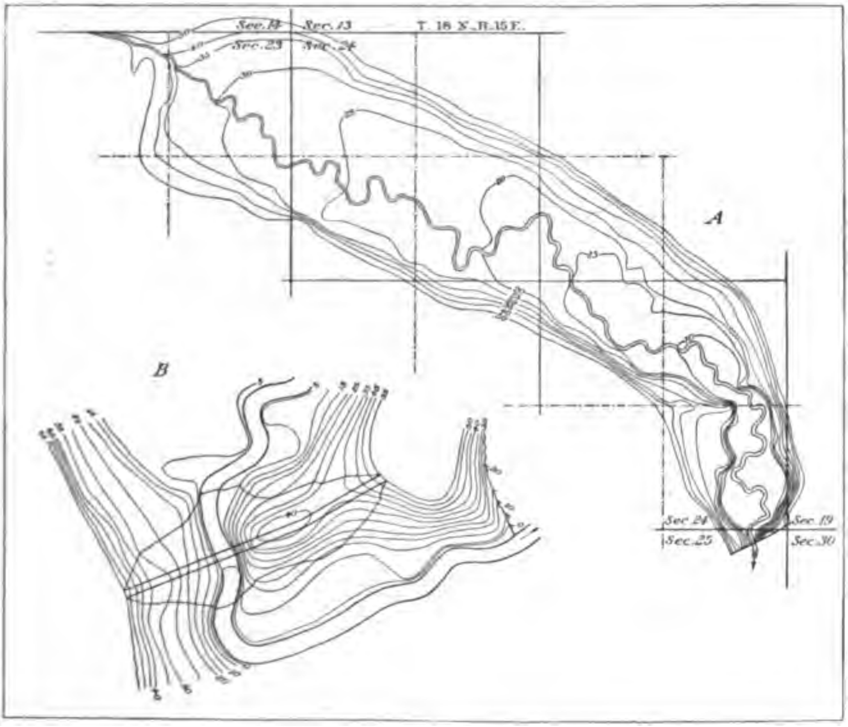

FIG. 47.—Contour map of Twin Valley reservoir and dam site.

The dam estimated upon is of the same type as that described for the Donner Lake and the Independence Lake reservoirs, with the same slopes and a top width of 20 feet.

Estimate of cost of Twin Valley reservoir.

Dam:		
Preparing foundation		$1,000
Earth embankment, 72,000 cubic yards, at $0.25		18,000
Riprap revetment, 7,800 square yards, at $0.50		3,900
Outlet works:		
250-foot tunnel with approaches	$1,250	
260 feet of 30-inch cast-iron pipe, at $8 laid	2,080	

Outlet works—Continued.		
Concrete encasing pipe, cut-off walls, and tunnel portals, 160 cubic yards, at $10	$1,600	
Valve, gate, and hoist	820	
		$5,750
Wasteway, complete		2,600
Right of way over flooded lands and damages		3,200
Engineering		3,000
Contingencies, 10 per cent		3,745
Total		41,195

Cost per acre-foot of storage, $5.27.

LITTLE TRUCKEE RESERVOIR.

This site is on Little Truckee River, between Webber Lake and its junction with Independence Creek. It occupies a valley of irregular width, extending about 3 miles up from the narrow canyon through which the stream flows, and where it is proposed to construct the impounding dam, which is to have a maximum height of 87 feet and a length of 409 feet. The area of the reservoir with a dam of this height is 710 acres, and the capacity 20,540 acre-feet. The dam estimated upon is of earth, of the hydraulic-fill type, the conditions being favorable for this method of construction. The wasteway will be at the south end of the dam, discharging back into the stream several hundred feet beyond its lower toe. The capacity of reservoir at various elevations is given in the table on the following page.

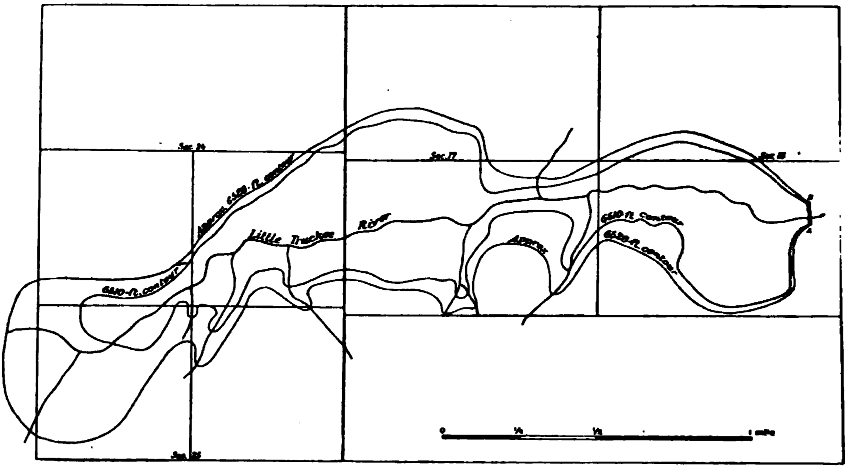

FIG. 48.—Contour map of Little Truckee reservoir site.

Area and capacity of proposed Little Truckee reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
6,465	10	0
6,520	450	10,100
6,538	710	20,540

Nearly all of the land which would be flooded by this reservoir is in private ownership, and part of it is under fence, though it is used only for pasturage during the summer time. The estimate of cost is as follows:

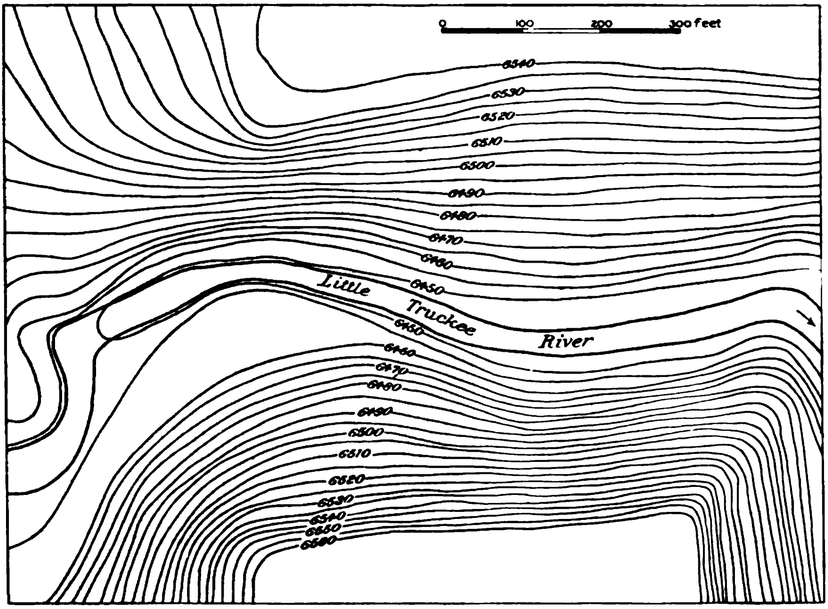

FIG. 49.—Plan of dam site of proposed Little Truckee reservoir.

Estimate of cost of proposed Little Truckee reservoir.

Dam:		
Hydraulic fill, 150,000 cubic yards, at $0.10		$15,000
2½ miles of ditch to supply water for fill		1,500
Preparing foundation		1,000
Riprap revetment, 8,000 square yards, at $0.75		6,000
Outlet works:		
900 feet of 30-inch cast-iron pipe, at $8 laid	$7,200	
330 cubic yards of concrete incasing pipe, at $8.50	2,805	
160 cubic yards of concrete for gate tower, at $10	1,600	
Valves, gate, and hoist complete	1,250	
Cable-suspension footbridge and gatehouse	845	
		13,700

Wasteway	$4,000
Damages to land and improvements	10,000
Engineering	5,000
Contingencies, 10 per cent	5,620
Total	61,820

Cost per acre-foot of storage capacity, $3.01.

HENNESS PASS VALLEY RESERVOIR.

This site occupies a small basin immediately to the north of the valley of Little Truckee River, opposite the junction of that stream and Independence Creek, from which it is separated by a narrow rock ridge. The immediate drainage area consists of 4½ square miles of undulating ridges, practically bare of timber. The main water supply for the reservoir will be drawn from Little Truckee River, by means of a canal about 4 miles in length, having a capacity of 100 cubic feet per second and heading a short distance below the dam for Little Truckee reservoir, last described. The maximum height of the dam will be 56 feet, its top length 720 feet, and its top width 24 feet. It will be of earth, of the hydraulic-fill type. The estimated capacity of the reservoir is 17,000 acre-feet. The following is an estimate of the cost:

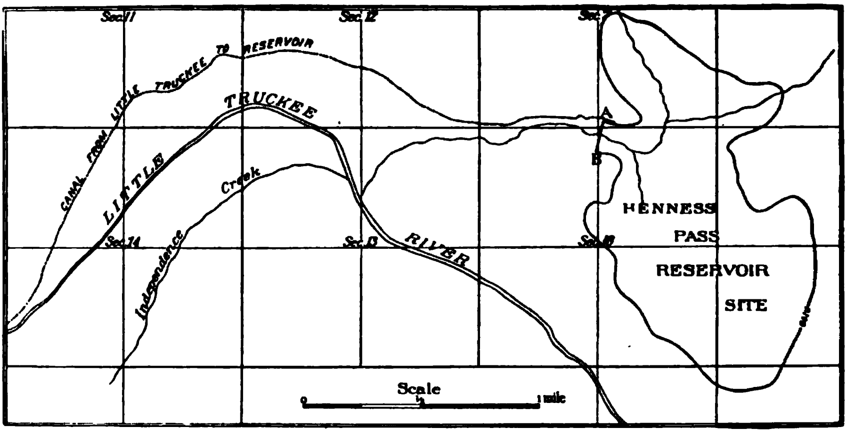

FIG. 50.—Map of Henness Pass Valley reservoir site and supply canal.

Estimate of cost of proposed Henness Pass Valley reservoir.

Dam:	
Hydraulic embankment, 108,850 cubic yards, at $0.10	$10,880
Preparing foundation	1,000
Riprap revetment, 8,400 square yards, at $0.50	4,200
Supply canal complete, 4 miles, at $3,000	12,000

Outlet works:		
620 feet 30-inch cast-iron pipe, at $8, laid	$4,960	
260 cubic yards concrete incasing pipe, at $8.50	2,210	
Gates and hoist complete	1,000	
		$8,170
Right of way		3,000
Engineering		4,000
Contingencies, 10 per cent		4,325
Total		47,575

Cost per acre-foot of storage capacity, $2.80.

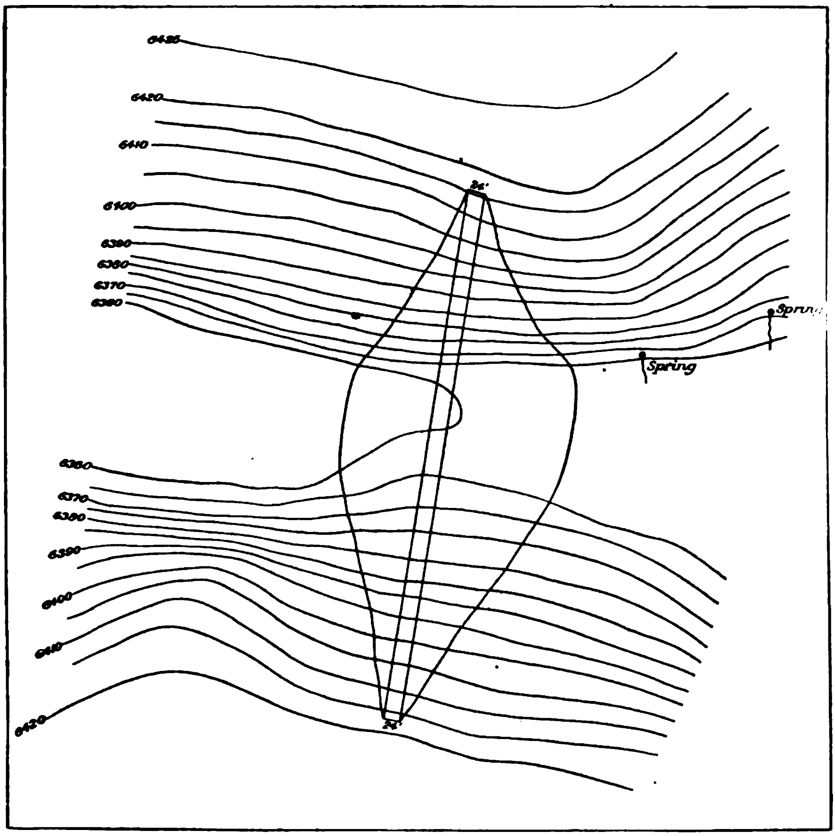

FIG. 51.—Plan of Henness Pass Valley dam site.

DOG VALLEY RESERVOIR.

This site occupies a small valley between outlying spurs of the Sierra Nevada, just west of the boundary line between California and Nevada and about 4 miles northwest of the town of Verdi in the latter State. The elevation is about 5,700 feet above sea level. It is found that by the construction of a dam with a maximum height of 65 feet and a top length of 235 feet a reservoir having a surface area of 274 acres and a capacity of approximately 5,785 acre-feet will be formed. No exact data of the water supply of this site have been collected, but it is believed, from a study of the run-off of adjoining basins, that the annual yield is considerably in excess of the capacity of the reservoir. The dam will be of the rock-fill type, with an earthen face on the upper side. The slope of the rock-fill on the lower side will be 1½ horizontal to 1 vertical, and vertical on the line of contact with the earth. The earthen portion of the dam will have a slope of 2½ to 1 on the upstream face. The outlet will be by means of a cast-iron pipe embedded in concrete in a tunnel run through the bed rock in projecting abutment.

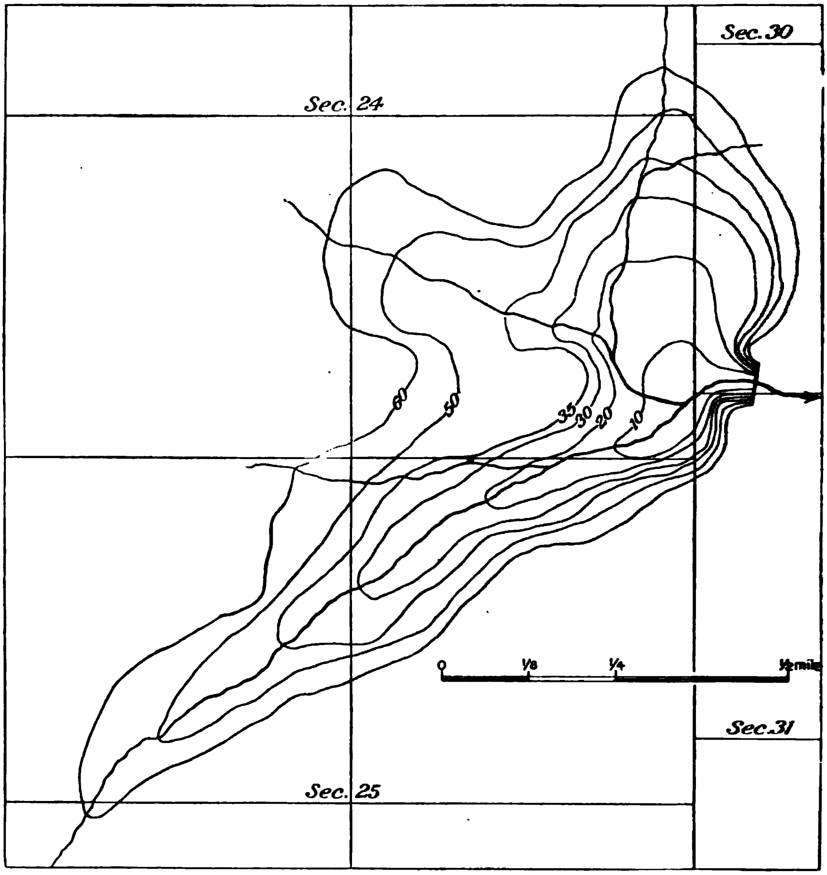

Fig. 52.—Contour map of Dog Valley reservoir site.

The first of the following tables gives the area and capacity of this site; the second, the estimated cost of the reservoir:

Area and capacity of proposed Dog Valley reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
5,700	Base of dam.	0
5,710	[a] 10	0
5,720	36	230
5,730	74	780
5,735	110	1,240
5,750	188	3,475
5,760	274	5,785

[a] Level of outlet gates.

Estimate of cost of proposed Dog Valley reservoir.

Dam:		
Rock filling, 13,380 cubic yards, at $0.75		$10,035
Earth embankment, 25,500 cubic yards, at $0.25		6,375
Riprap revetment, 2,800 square yards, at $0.50		1,400
Preparing foundation		500
Outlet works:		
300-foot tunnel, 3½ by 5 feet, at $6	$1,800	
300 feet of 24-inch cast-iron pipe, at $5	1,500	
110 cubic yards of concrete incasing pipe, etc., at $10	1,100	
Gates and hoist, complete	500	
		4,900
Wasteway, complete		1,250
Rights of way		1,800
Engineering		3,000
Contingencies, 10 per cent		2,926
Total		32,186

Cost per acre-foot of storage capacity, $5.564.

WATER SUPPLY.

An inquiry was also instituted as to the existing rights to the waters of Truckee River which have become vested and which should not be disturbed. At the present time the waters of the river are employed to generate power by eight companies at as many points on the stream. It was found that at Truckee, 14 miles from the outlet of Lake Tahoe, there would be required a flow of 160 second-feet from March 1 to December 1 and 110 second-feet for the remainder of the year. At Floriston the maximum flow required is 320 second-feet and the minimum flow 300 second-feet, and these quantities are more than sufficient to supply all of the requirements of the power plants below.

There are 27,493 acres of land in Reno Valley which are supplied with water by canals from Truckee River. With a duty of water of 1 second-foot to 100 acres this area will require 275 second-feet, which is less than the amount required for power purposes above.

It is believed that the water supply, reenforced and regulated by storage reservoirs, will be sufficient not only to maintain the flow of Truckee River at a minimum of 300 second-feet, but also, if properly applied, to irrigate 230,000 acres of land, as follows:

Irrigable lands in Truckee Basin.

	Acres.
In Washoe Valley and on Steamboat Creek	11,000
From small tributaries of river	3,000
In Reno Valley, from Truckee River	42,000
On foothills north of Truckee River and in Lemmon, Prosser, Warmsprings, and Spanish Springs valleys	75,000
Below Reno Valley and northward from Wadsworth	24,000
East and southeast of Wadsworth	75,000
Total	230,000

Two canal systems have been planned to utilize the stored waters. The first, with a capacity of 550 second-feet, to head in Truckee River near Floriston, would irrigate 75,000 acres of arable land north and east of Reno, at a cost, for diversion canal, headworks, and main branches, of $1,350,000; the second canal, with a capacity of 750 cubic feet per second, to head on the south side of Truckee River above Clarks station, and to continue to a short distance above Wadsworth, where a branch with a capacity of 225 second-feet can be taken across the river by pressure pipes and be led northward toward Pyramid Lake, while the main branch, with a capacity of 525 second-feet, can be continued southeast and east from Wadsworth, the two branches supplying water to 99,000 acres of land, of which about 30,000 acres are in the Truckee Basin (more than 20,000 acres of this is in the Pyramid Lake Indian Reservation) and 69,000 acres in the basin of Carson River, approximately 50,000 acres of the latter being in Carson Sink Valley. The cost of this canal system, including the principal distributing branches, will approximate $500,000.

Another plan which is being examined is to carry all the waters of the Truckee to the valley of the Carson, the winter flow to be stored for future use in the Lower Carson reservoir.

If all of the water can be used in the valley of the Carson, it is probable that the cost per acre for the irrigating works would be considerably less than on the High Line Canal and the canal systems above referred to.

The items of cost for this project would be:

(1) The dams and reservoirs in Truckee drainage basin.
(2) Diversion dam and headworks at Clarks on Truckee River.
(3) About 30 miles of canal to carry the waters of Truckee River to the Lower Carson reservoir.
(4) The Lower Carson reservoir and dam.
(5) The main canals for distribution of water.

The surveys for this part of the project are not yet completed, so that definite estimates can not be given at this date.

SUMMARY.

The following table gives the gross and net capacities and the cost of the proposed storage reservoirs in Truckee Basin:

Proposed storage reservoirs in Truckee Basin.

Name of reservoir.	Gross capacity.	Net capacity, which can be drawn annually.	Total cost.
	Acre-feet.	*Acre-feet.*	
Lake Tahoe	745,400	200,000	$32,461
Donner Lake	26,900	26,900	86,746
Independence Lake	11,725	11,725	33,979
Twin Valley	7,818	7,818	41,195
Little Truckee	20,540	20,500	61,820
Henness Pass Valley	17,000	16,000	47,575
Dog Valley	5,785	5,785	32,186
Total	835,168	288,728	335,962

CARSON RIVER DIVERSION.[a]

WATER STORAGE.

Surveys and investigations have been conducted in the basin of Carson River with a view to devising means for increasing the water supply of the arable lands. Among other matters the amount of rainfall has been observed at various places in and adjacent to the basin.

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[a] From report of L. H. Taylor.

The following table gives the annual precipitation at a number of these places, and shows the increase for each 100-foot rise in elevation, with St. Clair as a base:

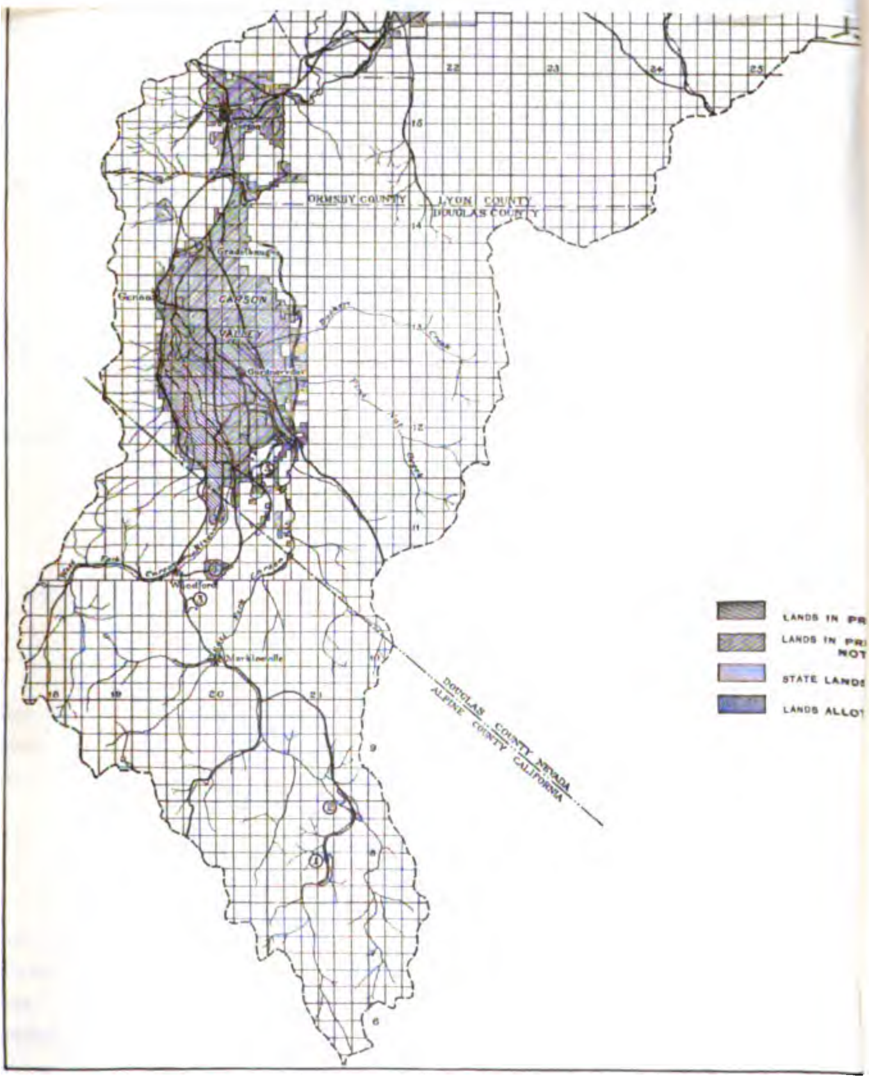
Increase of precipitation in Carson Basin for each 100 feet of elevation.

[Season of year, September 1 to August 30.]

Station.	Rainfall.	Elevation.	Difference in elevation.	Increase of rainfall for each 100-foot rise.
	Inches.	*Feet.*	*Feet.*	*Inches.*
St. Clair	4.90	4,000	0	0
Carson	12.33	4,670	670	1.26
Martin's ranch	7.11	4,700	700	.32
Genoa	16.69	4,824	824	1.43
Lewer's ranch	25.15	5,177	1,177	1.72
Virginia City	17.71	6,242	2,242	.57
Marlette Lake	32.71	7,800	3,800	.73
Tamarack	44.60	8,100	4,100	.97
Mean				1.00

WATER SUPPLY.

Gaging stations have been maintained on both East and West forks of Carson River. On the former the station is at Rodenbah's ranch, near Gardnerville, Nev. Results of measurements from April, 1890, to December, 1892, will be found in the Thirteenth Annual Report, Part III, page 95, and for 1900 and 1901 on page 249 herein. The station on the West Fork is at Woodfords, Cal., and results of measurements from April, 1890, to March, 1892, will be found in the Thirteenth Annual Report, Part III, page 96, and for 1900 and 1901 on page 249 herein. The tables on page 249 give also the estimated mean monthly discharge of the two streams during the time measurements have been made.



IRRIGATED LANDS AND RESERVOIR SITES ON C

Estimated monthly discharge of West Fork of Carson River at Woodfords, Cal.

[Drainage area, 70 square miles.]

Month.	Discharge in second-feet.						Run-off.		
	1890.	1891.	1892.	1900.	1901.	Mean.	Total.	Per square mile.	Depth.
							Acre-feet.	*Sec.-ft.*	*Inches.*
January	.....	52	45	.....	51	49	3,013	0.70	0.807
February	.....	48	46	.....	111	68	3,777	.97	1.012
March	.....	61	65	.....	170	99	6,087	1.41	1.630
April	284	127	.....	.....	234	215	12,794	3.07	3.427
May	657	534	.....	.....	472	554	34,065	7.91	9.125
June	614	338	.....	.....	289	414	24,635	5.91	6.599
July	380	130	.....	.....	136	215	13,220	3.07	3.541
August	135	65	.....	.....	77	92	5,657	1.31	1.516
September	75	41	.....	.....	43	53	3,154	.76	.845
October	67	48	.....	44	49	52	3,197	.74	.856
November	49	43	.....	48	56	49	2,916	.70	.781
December	53	47	.....	53	76	57	3,505	.81	.939
The year	.....	128.39	.....	.....	147.20	160.25	116,020	2.289	31.078

Estimated monthly discharge of East Fork of Carson River at Rodenbah's ranch near Gardnerville, Nev.

[Drainage area, 381 square miles.]

Month.	Discharge in second-feet.						Run-off.		
	1890.	1891.	1892.	1900.	1901.	Mean.	Total.	Per square mile.	Depth.
							Acre-feet.	*Sec.-ft.*	*Inches.*
January	......	388	390	......	34	271	16,667	0.712	0.820
February	......	402	388	......	664	485	26,936	1.273	1.326
March	......	783	422	......	464	556	34,188	1.459	1.682
April	1,026	452	478	......	582	635	37,786	1.667	1.860
May	2,654	1,445	1,226	......	1,822	1,787	109,881	4.690	5.408
June	2,430	1,328	1,158	......	1,500	1,604	95,446	4.210	4.697
July	1,789	618	506	......	743	914	56,201	2.399	2.766
August	597	408	413	......	259	419	25,764	1.100	1.268
September	415	388	414	......	139	339	19,172	.890	.943
October	386	385	416	38	137	272	16,725	.714	.823
November	384	385	414	41	196	284	16,889	.745	.832
December	379	438	1,097	34	279	445	27,363	1.168	1.346
The year	......	620	611	......	567	667	483,028	1.751	23.771

Of the reservoir sites in the upper basin of the river shown on the map (Pl. XXXV), three have been surveyed in detail—viz, Silver King, Diamond Valley, and Mud Lake—and the details of the cost and the necessary control works of each are given on the following pages. It is believed that these three reservoirs are of sufficient capacity, if employed to supplement the low-water flow of the streams, to irrigate 70,000 acres, or practically all of the available land above the Empire gaging station on Carson River. During ordinary years the two larger reservoirs farther down the river—Alkali Flat and

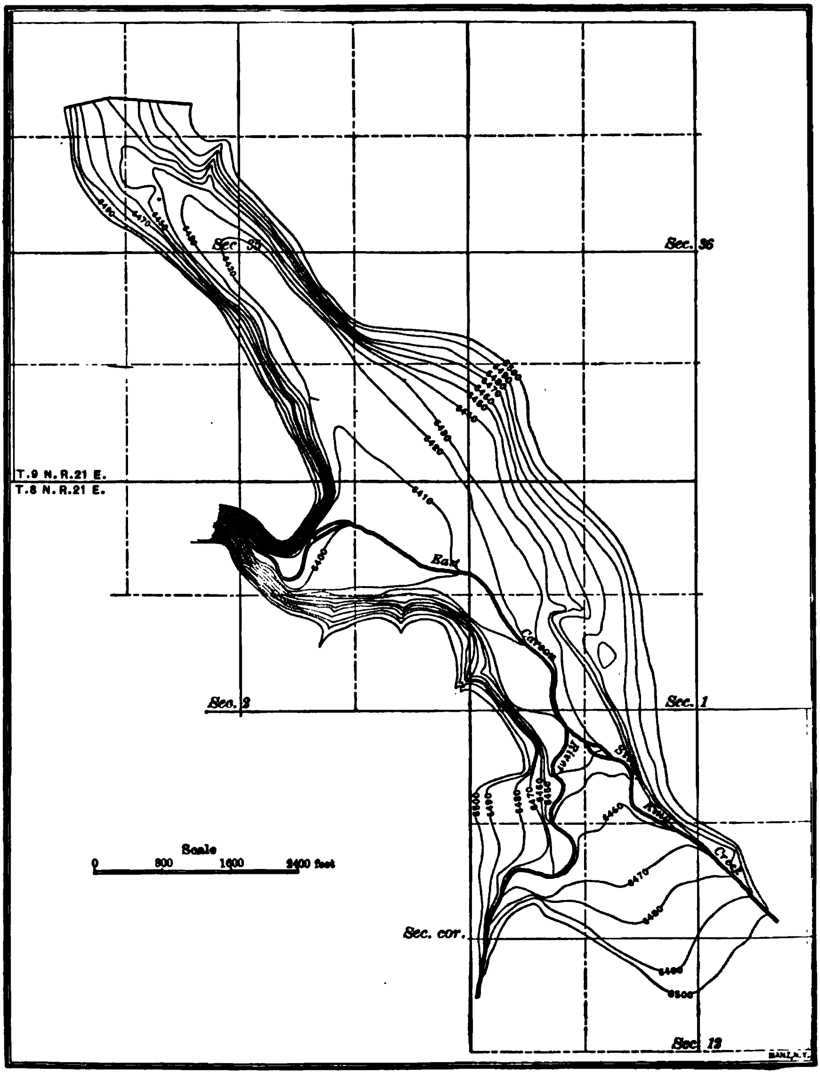
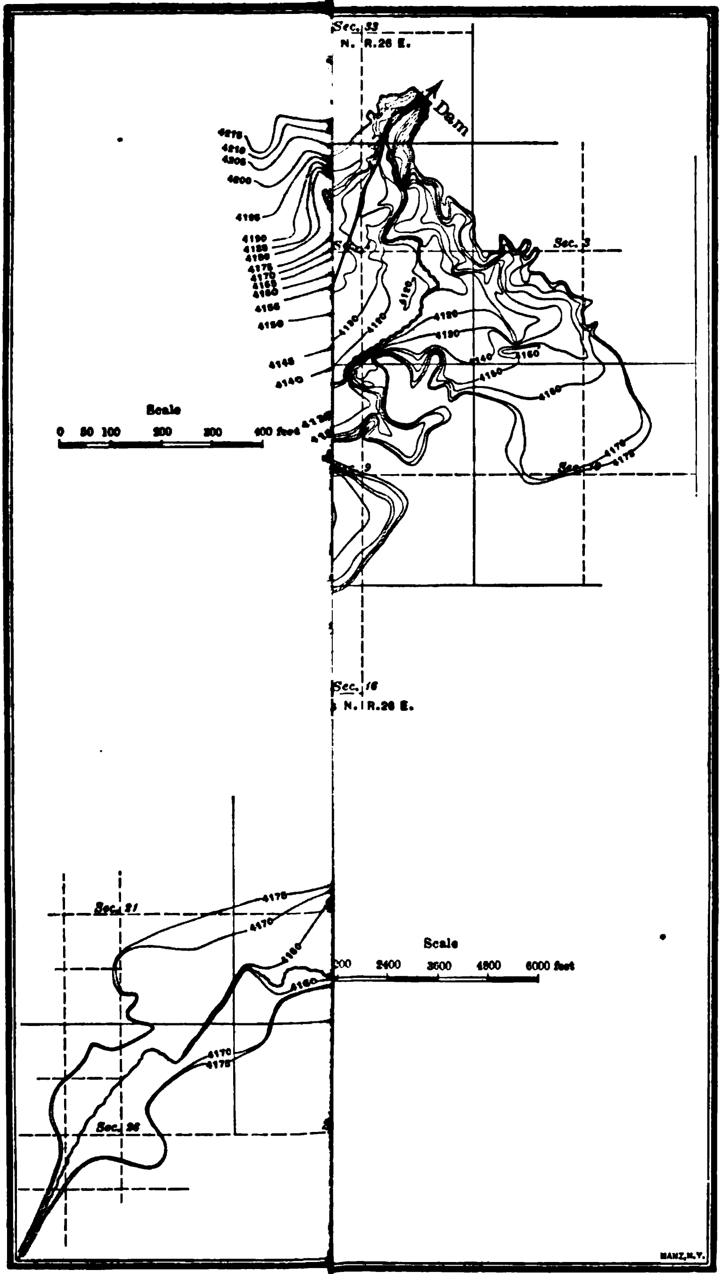


FIG. 53.—Contour map of Silver King reservoir site.


Sec. 33
N. R.26 E.
Dam
4275
4210
4205
4200
4195
4190
4185
4180
4175
4170
4165
4160
4155
4150
4145
4140
4130
4120
Sec. 3
Sec. 4
Sec. 9
Sec. 10
Scale
0 50 100 200 300 400 feet
Sec. 16
N. R.26 E.
Sec. 21
Sec. 28
Scale
200 2400 3600 4800 6000 feet
MANZ, N.Y.

Lower Carson—would have sufficient capacity to impound all of the surplus water over and above the requirements of the upper part of the basin. Their waters would be used on lands in the vicinity of Old Fort Churchill and in Carson Sink Valley. Complete estimates of the irrigation possibilities of the lower basin are not yet finished, but it is believed that they will be limited only by the water supply. Estimates of the cost of the control and outlet works in the two lower systems (Alkali Flat and Lower Carson) are also given herein.

SILVER KING RESERVOIR, ALPINE COUNTY, CAL.

For this reservoir two earthen dams will be required, a main dam and a secondary dam; the former to have a maximum height of 101 feet, a top length of 445 feet, and a top width of 20 feet; the secondary dam to have a maximum height of 36 feet, a top length of 1,300 feet, and a top width of 20 feet. For both dams the slopes on the upstream face will be 2½ to 1 and on the downstream face 2 to 1. With dams of these heights the capacity of the reservoir will be 22,555 acre-feet. A map of the reservoir site is shown in fig. 53. The first of the following tables gives the area and capacity of the reservoir at various elevations; the second table gives the estimated cost.

Area and capacity of proposed Silver King reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
6,395	0	[a] 0
6,400	6	[b] 0
6,410	52	290
6,420	125	1,175
6,430	176	2,680
6,440	227	4,695
6,450	272	7,190
6,460	319	10,145
6,470	383	15,655
6,480	441	17,775
6,490	515	22,555

[a] Base of dam. [b] Level of outlet.

Estimate of cost of proposed Silver King reservoir.

Main dam, 187,000 cubic yards of earth, at $0.30		$56,100
Secondary dam, 91,000 cubic yards of earth, at $0.20		18,200
Riprap revetment, 16,000 square yards, at $0.70		11,200
Preparing foundations		2,200
Outlet works:		
Outlet tunnel, 500 feet, 6 by 7 feet, at $10	$5,000	
Shaft, 90 feet, at $12.50	1,125	

Outlet works—Continued.		
Lining shaft and cut-off walls in tunnel, 90 cubic yards of concrete, at $12.50	$1,125	
Steel pipe, 500 feet of 30-inch No. 6, at $7	3,500	
Gates, valves, and hoist	1,450	
		$12,200
Wasteway of 5,000 second-feet capacity		5,000
Right of way and damages		5,000
Engineering		6,500
Contingencies, 10 per cent		11,640
Total		128,040

Cost per acre-foot of storage, $5.68.

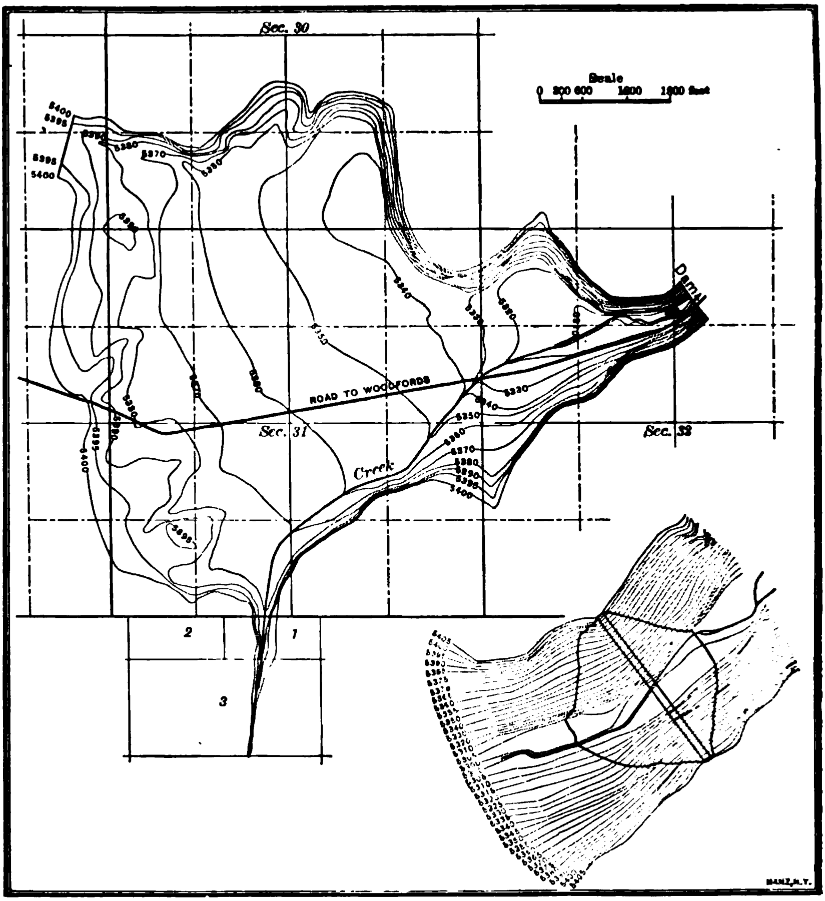


FIG. 54.—Contour map of Diamond Valley reservoir site.

DIAMOND VALLEY RESERVOIR, ALPINE COUNTY, CAL.

For this reservoir there will be required one dam, having a maximum height of 96 feet, a top width of 25 feet, a top length of 575 feet, and a slope on the upstream face of 3 to 1 and on the downstream face of 2 to 1. With a dam of this height the capacity of the reservoir will be 23,280 acre-feet. The following tables give the area and capacity of the reservoir at various elevations and the estimated cost. A map of the reservoir site is shown in fig. 54.

Area and capacity of proposed Diamond Valley reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
5,300	0	[a] 0
5,310	6	30
5,320	38	250
5,330	64	760
5,340	120	1,680
5,350	233	3,445
5,360	381	6,515
5,370	508	10,960
5,380	622	16,610
5,390	712	23,280

[a] Base of dam and level of outlet.

Estimate of cost of proposed Diamond Valley reservoir.

Earth embankment, 242,000 cubic yards, at $0.25		$60,500
Riprap revetment, 12,000 square yards, $0.60		7,200
Preparing foundation		1,000
Outlet works:		
Tunnel, 500 feet, 6 by 7, at $12	$6,000	
Steel pipe, 500 feet 30-inch, No. 6, at $6.50	3,250	
Shaft, 25 feet, at $10	250	
Concrete for lining shaft, gate tower, tunnel portals, and cut-off walls, 190 cubic yards, at $11	2,090	
Gates, valves, and hoist	1,410	
		13,000
Wasteway of 500 second-feet capacity		1,500
Right of way and damages		18,000
Supply canal 7,000 feet long; bed width, 7 feet; top width, 17 feet; grade, 1 foot in 1,400 feet; capacity, 200 second-feet		8,000
Engineering		5,800
Contingencies, 10 per cent		11,500
Total		126,500

Cost per acre-foot of storage, $5.43.

MUD LAKE RESERVOIR, DOUGLAS COUNTY, NEV.

For this reservoir two earthen dams will be required, a main dam and a secondary dam, the former to have a maximum height at the center of 60 feet, a top length of 1,500 feet, a top width of 20 feet, and a slope on the upstream face of 3 to 1 and on the downstream face of 2 to 1; the secondary to have a maximum height of 11 feet, a top length of 2,100 feet, a width of 15 feet, and a slope on the upstream face of 4 to 1 and on the downstream face of 2 to 1. With dams of these dimensions the reservoir will have a capacity of 8,370 acre-feet. The outlines of the reservoir site are shown in fig. 55. The following tables give the area and capacity of the reservoir at various elevations and the estimate of cost.

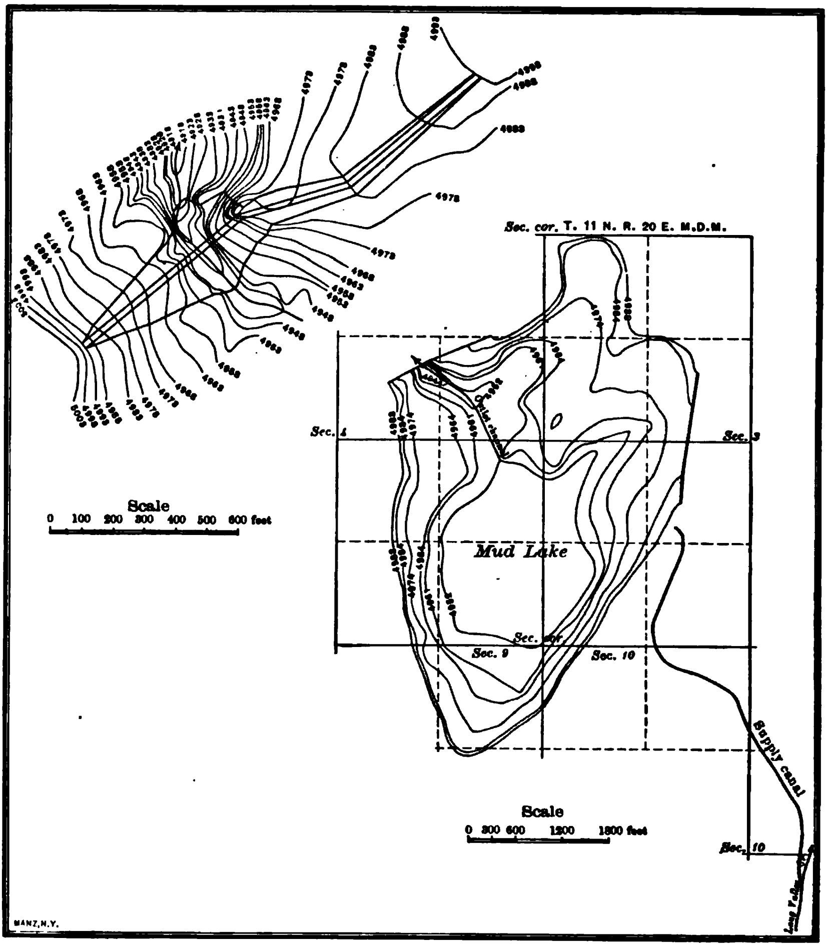


FIG. 55.—Contour map of proposed Mud Lake reservoir.

Area and capacity of proposed Mud Lake reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
4,933	0	[a] 0
4,944	1	[b] 0
4,952	4	[c] 20
4,952	[d] 84	....
4,961	144	[e] 1,046
4,964	183	1,536
4,974	273	3,816
4,984	349	6,926
4,988	373	8,370

[a] Base of dam at lowest part.
[b] Level of outlet.
[c] Below present reservoir.
[d] Including present reservoir; estimated.
[e] High-water level in present reservoir.

Estimate of cost of proposed Mud Lake reservoir.

Earth embankment:		
Main dam, 92,000 cubic yards, at $0.18		$16,560
Secondary dam, 26,000 cubic yards, at $0.10		2,600
Riprap revetment, 9,200 square yards, at $0.70		6,440
Preparing foundations		900
Outlet works:		
Tunnel, 5 by 6 feet, 240 feet, at $7	$1,680	
Shaft, 30 feet, at $10	300	
Steel pipe, 240 feet, 24-inch No. 8, at $3	720	
Concrete for lining shaft, gate tower, portals of tunnel, cut-off walls, etc., 50 cubic yards, at $11	550	
Gates, valves, and hoist	850	
		4,100
Wasteway of 150 second-feet capacity		150
Supply canal from Long Valley Creek; length, 5,000 feet; sectional area, 27 square feet; grade, 1 in 800; capacity, 100 second-feet		750
Right of way		1,000
Engineering		3,000
Contingencies, 10 per cent		3,550
Total		39,050

Cost per acre-foot of storage, $4.66+.

ALKALI FLAT RESERVOIR, LYON COUNTY, NEV.

This reservoir is a natural basin which will be filled by a conduit from Carson River consisting of 77,200 feet of canal and 13,000 feet of bench flume. The grades and widths adopted are as set forth in table on the following page.

Grades and widths of proposed Alkali Flat conduit.

Location.	Grade.	Bed width.
	Feet.	*Feet.*
Canal from station 0 to station 436	1 in 1,800	20
Canal from station 436 to station 753	1 in 3,300	25
Canal from station 753 to station 766	1 in 1,800	20
Flume from station 766 to station 896	1 in 1,800	16
Canal from station 896 to station 902	1 in 1,800	20

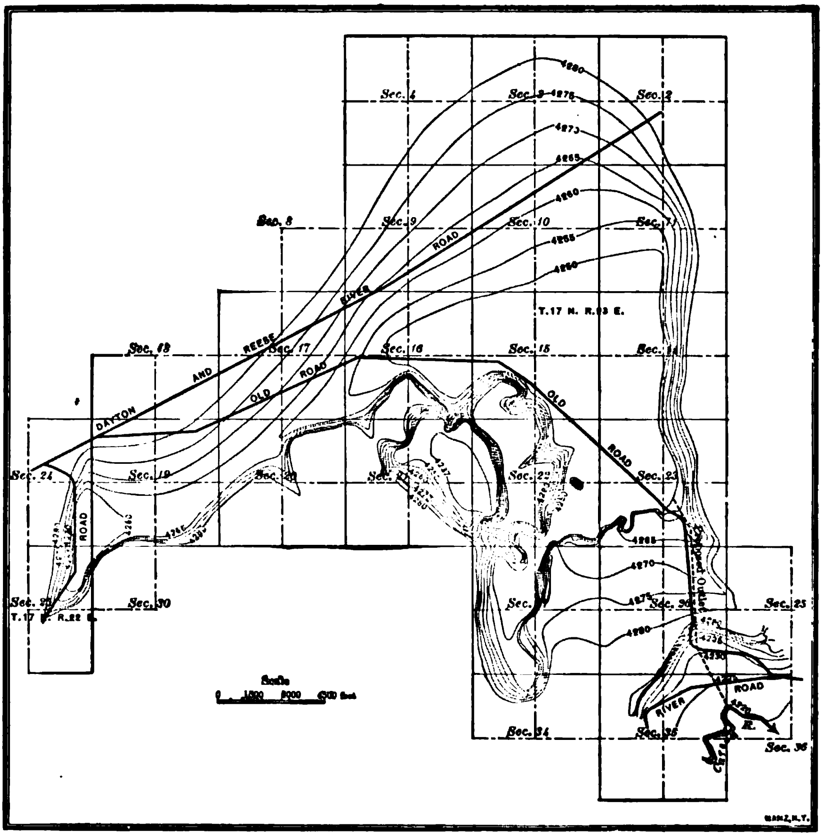
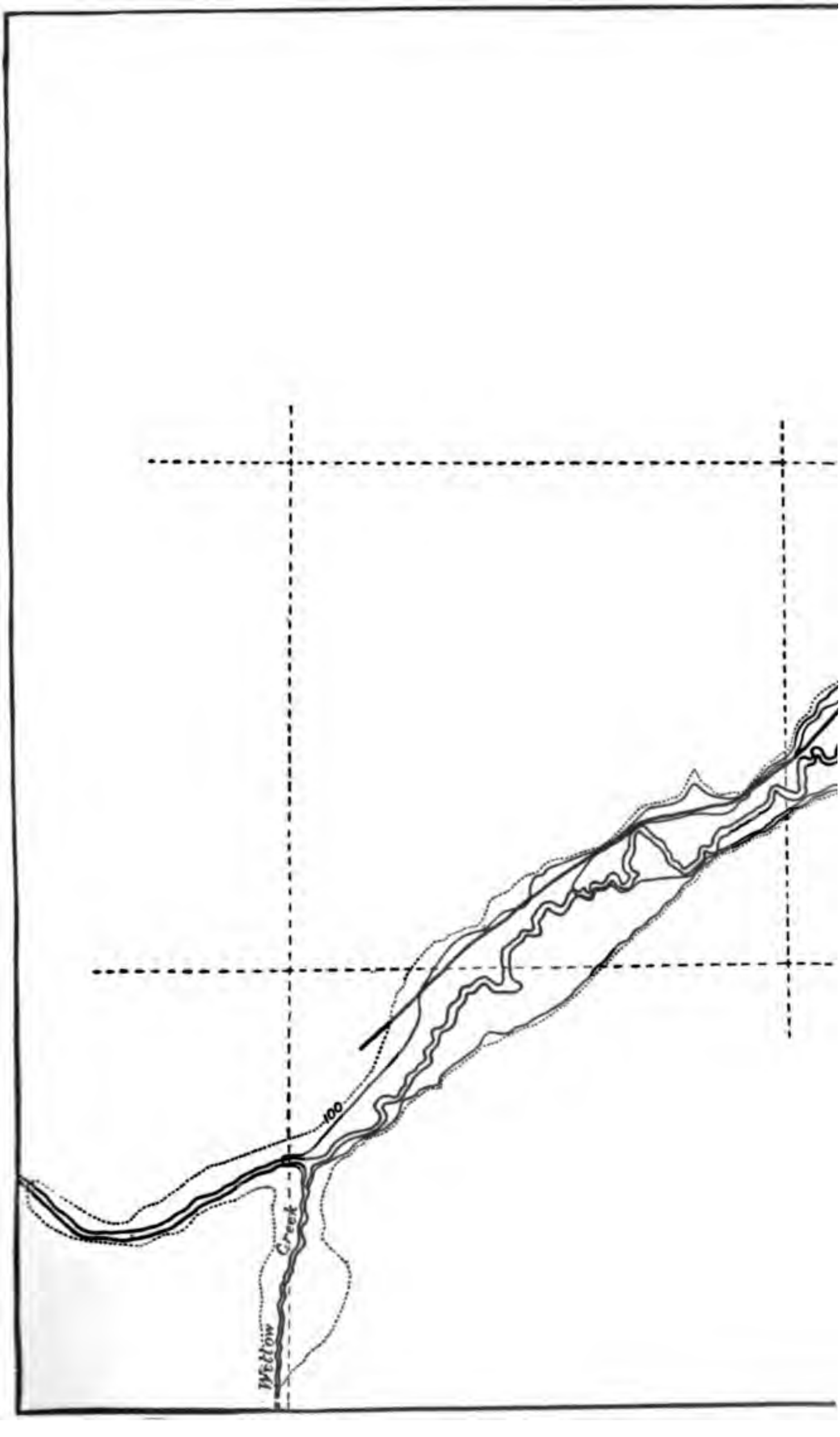


FIG. 56.—Contour map of Alkali Flat reservoir.

The depth of water will be uniformly 7 feet. The water will be drawn from the reservoir by a canal cut through the natural bank for a distance of 8,700 feet, a short portion of which will be constructed as a tunnel, so as to leave a natural dam for confining the waters. The bed width of the canal inside of the reservoir basin from station 0 to station 17 will be 30 feet, the side slopes 5 to 1; from station 17 to station 50 the bed width will be 30 feet, the slope 1 to 1 up to 7 feet


100
Willow
Creek

and 1½ to 1 above, the 1 to 1 slopes to be riprapped, with stone wall extending 4 feet below canal bed. The bed width of the canal outside of the reservoir basin, or from station 51 to station 87, will be 30 feet, the slopes 1 to 1 up to 7 feet and 1½ to 1 above, the 1 to 1 slopes from station 51 to station 60 to be riprapped. In the canal outside of the reservoir basin are four 5½-foot falls of concrete.

The water will be drawn through four cast-iron pipes of 48 inches diameter, each laid in a tunnel through natural earth at stations 50 to 51, and surrounded by concrete. These pipes will discharge into a basin providing a water cushion 4 feet in depth. The upstream face of the natural embankment pierced by the outlet pipes will be cut to a slope of 1 to 1, and will be faced with two layers of concrete, with a thin layer of asphaltum between. The downstream face of the embankment will have a slope of 1½ to 1.

Area and capacity of proposed Alkali Flat reservoir.

Contour.	Area.	Capacity.
Feet.	*Acres.*	*Acre-feet.*
4,250	2,055	[a] 0
4,255	2,642	11,742
4,260	3,293	26,580
4,265	4,646	46,428
4,270	5,371	71,470
4,275	6,486	101,113
4,280	7,669	136,500

[a] Level of outlet.

Estimate of cost of proposed Alkali Flat reservoir.

Diversion weir and regulator:		
Excavating foundation	$475	
Concrete, 425 cubic yards, at $8	3,400	
Lumber, 5 M feet B. M., at $25	125	
		$4,000
Supply canal:		
Excavation, 840,000 cubic yards		131,000
Flume, 2,250 M feet B. M. of lumber, at $30		67,500
Outlet works:		
Excavation, 417,000 cubic yards, at $0.10 to $0.17		58,500
Cast-iron pipe, 420 feet of 48-inch, at $16 laid	$6,720	
Four special curved 48-inch castings, 50-foot lengths, at $25 a foot	1,250	
Four hinged flap valves, 48-inch, with hoists, at $400	1,600	
Four 48-inch low-pressure screw valves, at $650	2,600	
		12,170
Concrete, etc., at outlet gates, 1,600 cubic yards, at $11		17,600
Concrete in falls, 883 cubic yards, at $10		8,830
Slope paving, 15,000 square yards, at $1		15,000
Engineering		15,400
Contingencies, 10 per cent		33,000
Total		363,000

Since the supply canal for this reservoir will command 12,000 or more acres of land not now under irrigation, at least $60,000 of the foregoing estimate should be charged to that, thus reducing the cost of storage to $303,000 net, or at the rate of $2.22 per acre-foot of reservoir capacity.

LOWER CARSON RESERVOIR, CHURCHILL AND LYON COUNTIES, NEV.

For this reservoir it is proposed to construct a concrete-rubble weir dam, having a maximum height of 110 feet above river bed, a top length of 725 feet, and bottom length of 85 feet.

There will be two outlets, through separate tunnels; the one on the right bank being at an elevation 20 feet higher than the other, in order to command the irrigable lands on that side of the river.

The tunnel on the left bank will discharge into the river channel the water to be diverted some miles below.

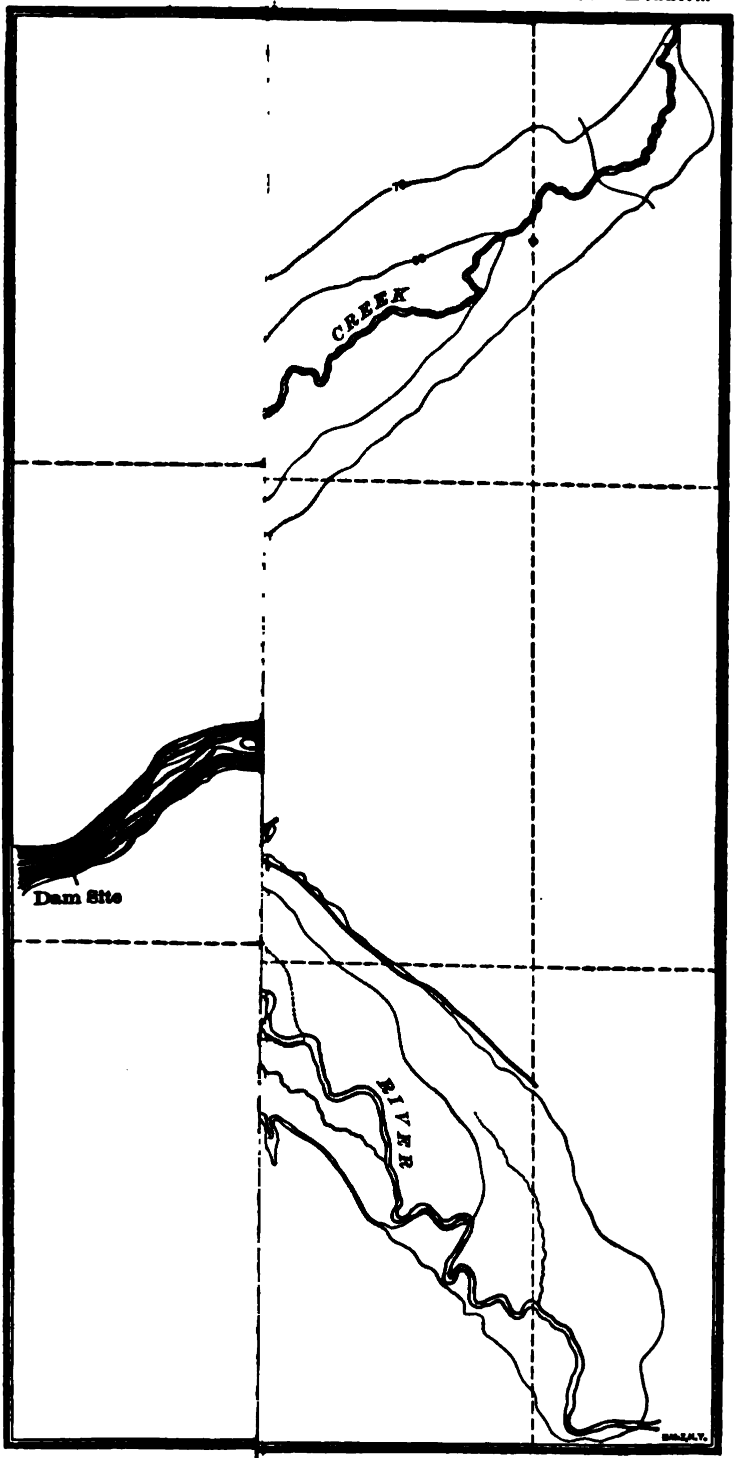
The water will be admitted to the tunnels through suitable masonry towers, which will also act as piers for a light steel bridge from one side of the river to the other. The estimated cost of this dam is $450,000. The capacity of the reservoir with height of dam proposed will be 270,000 acre-feet, making cost per acre-foot of storage capacity $1.67.

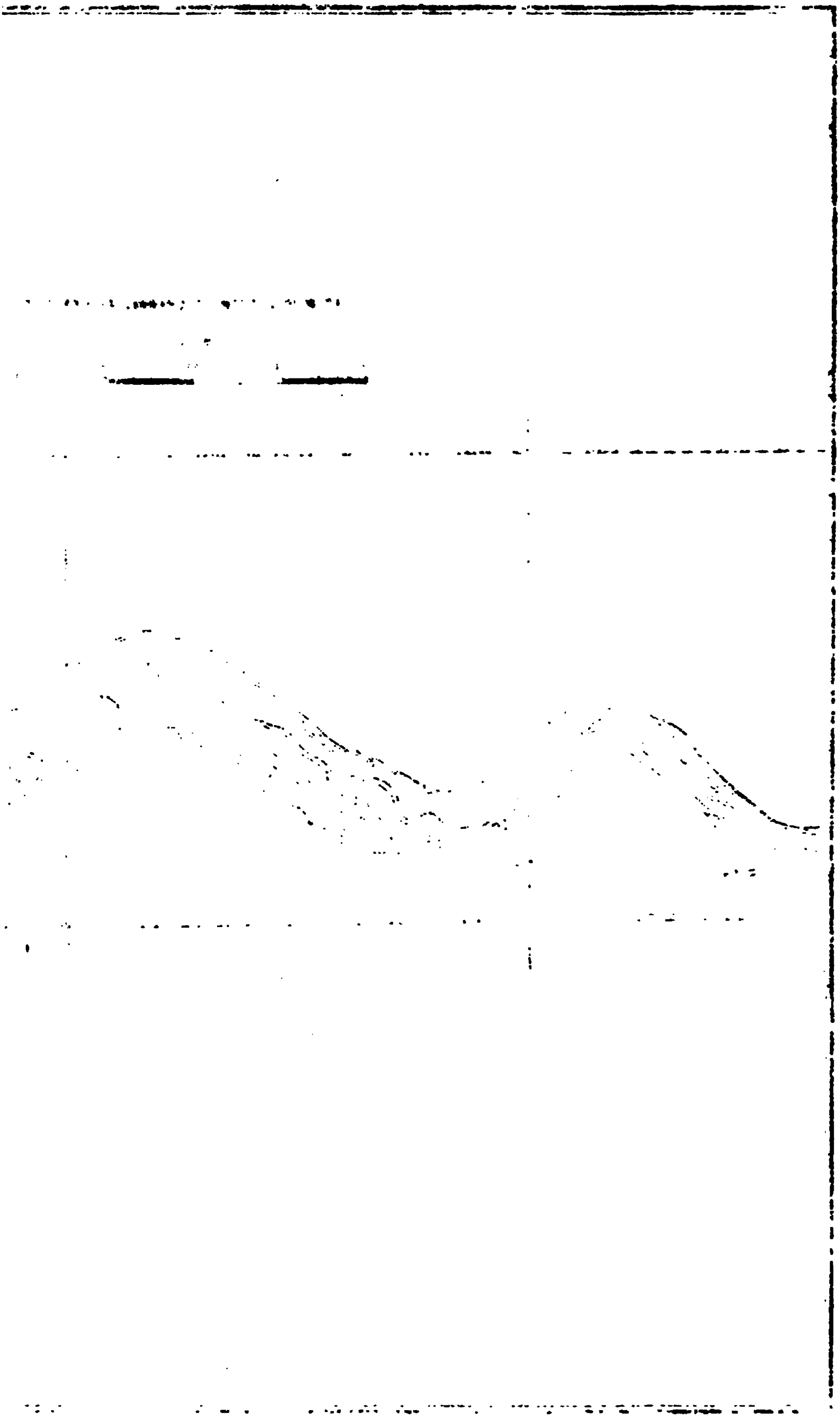
HUMBOLDT RIVER STORAGE.

Two reservoir sites have been surveyed in the drainage basin of Humboldt River, the field work being carried on by Jeremiah Ahern. One of these is on the South Fork, in Elko County, a short distance below the mouth of Tenmile Creek. A map of the site was made, on a scale of 1,000 feet to 1 inch. The other reservoir site is on the North Fork, above Beaver Creek, in Elko County, and was mapped on a scale of 1,000 feet to 1 inch. The following tables give the capacity and area of the two sites for each 10-foot contour:

Area and capacity of reservoir site on North Fork of Humboldt River, in Elko County, Nev.

Contour.	Area.	Section capacity.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0	0	0
10	14	71	71
20	111	627	698
30	333	2,219	2,917
40	629	4,806	7,723
50	979	8,036	15,759
60	1,356	11,672	27,431
70	1,737	15,464	42,895
80	2,157	19,472	62,367
90	2,551	23,542	85,909
100	2,950	27,505	113,414


CREEK
Dam Site
RIVER



Area and capacity of reservoir site on South Fork of Humboldt River, in Elko County, Nev.

Contour.	Area.	Section capacity.	Total capacity.
Feet.	*Acres.*	*Acre-feet.*	*Acre-feet.*
0	0	0	0
10	5.28	26	26
20	33.29	193	219
30	125.03	797	1,016
40	250.69	1,884	2,900
50	437.33	3,440	6,340
60	794.08	6,157	12,497
70	1,311.75	10,529	23,026

NEW MEXICO.

In this Territory development of the agricultural resources is largely dependent upon the best use of the waters of the Rio Grande and its principal tributary on the east, Pecos River. The utilization of the Rio Grande offers many difficult problems. This stream rises in central Colorado and flows south through the entire length of New Mexico, becoming the international boundary between the United States and Mexico. The waters of the river in Colorado are used to a large extent in San Luis Valley, and a number of small canals and ditches are taken out all along its course in New Mexico. In the southern part of the Territory the river is frequently dry in summer, and during the brief flood period of spring so large an amount of mud is transported that the maintenance of ditches is difficult and expensive. Water storage must be resorted to, but the obstacles to this are serious, both on account of a large amount of mud and because of the uncertainty of obtaining proper foundations for a substantial structure.

An attempt has been made by a corporation to begin water storage at what is known as Elephant Butte, but this resulted in protracted litigation in the United States courts, involving questions of the navigability of the lower river and the consideration of international distribution of the water. Pending the settlement of this case the construction of storage works on the Rio Grande and its tributaries has been held in abeyance.

Pecos River is east of the Rio Grande, flowing in a general direction parallel with it in New Mexico. Leaving this Territory, it flows across the western arid prolongation of Texas. The greater part of the drainage basin of this river lies in what is known as the Red Beds country, the rocks containing large quantities of gypsum, and this, passing into solution, causes the waters of the lower Pecos to be so heavily charged with mineral salts that its use in irrigation requires the most careful handling. Two large reservoirs have been built on the river above the town of Carlsbad, and irrigation has been developed to a considerable extent. There are other reservoir sites which may be utilized in the future if careful examination shows them to be as feasible as they are represented to be.

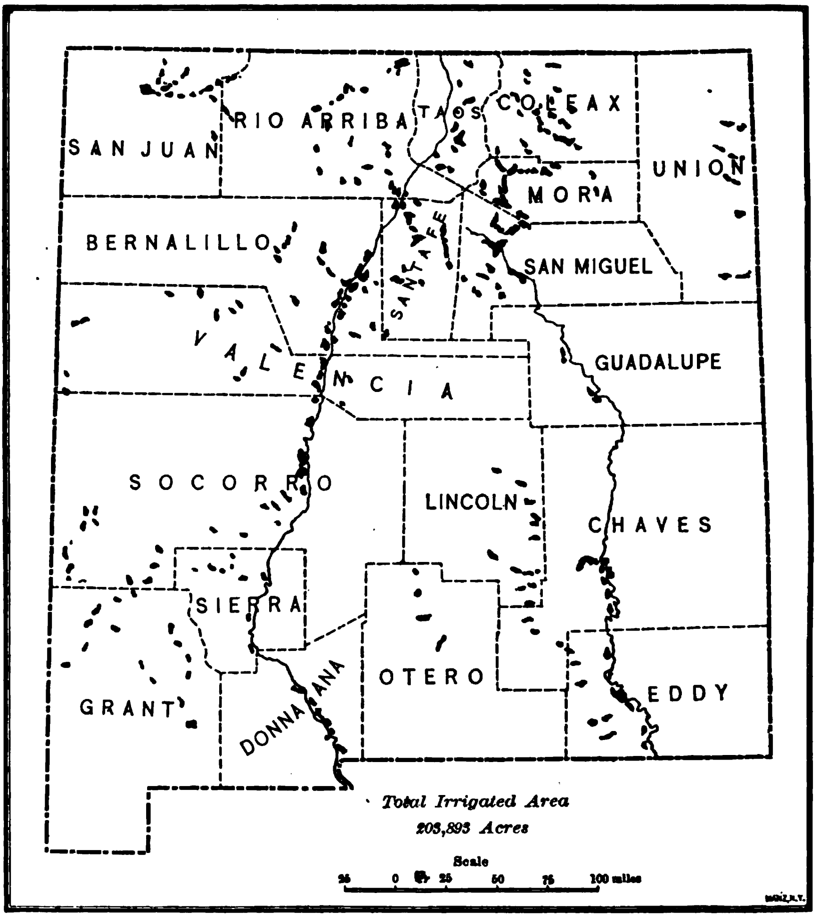


FIG. 57.—Map of irrigated areas in New Mexico.

By special grants of Congress large areas of land have been donated to the Territory for the purpose of irrigation and of improving the Rio Grande. These donations, however, correspondingly reduce the disposal of other public lands, and as a consequence the funds available for reclamation are small. In order to carry out the purposes of the donation a land board and a commission of irrigation have been created. As yet little has been accomplished beyond the selection of certain tracts of land and the consideration of plans.

The table below shows the condition on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in New Mexico on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Bernalillo	953,452	653,800	1,625,888	3,233,140
Chaves	6,793,285	3,280	576,235	7,372,800
Colfax	649,023	....	1,772,737	2,421,760
Donna Ana	2,722,282	335,378	142,980	3,200,640
Eddy	3,944,842	6,300	281,178	4,232,320
Grant	5,183,680	7,414	778,186	5,969,280
Guadalupe	3,706,201	....	765,479	4,471,680
Lincoln	2,737,997	106,924	344,839	3,189,760
McKinley	893,133	999,516	1,363,291	3,255,940
Mora	808,703	....	811,777	1,620,480
Otero	4,027,998	208,440	162,922	4,399,360
Rio Arriba	2,268,824	840,161	1,150,215	4,259,200
San Juan	1,473,396	1,958,400	243,084	3,674,880
San Miguel	1,572,753	202,550	1,317,817	3,093,120
Santa Fe	645,031	188,900	581,749	1,415,680
Sierra	1,820,570	74,875	107,115	2,002,560
Socorro	8,535,784	278,008	1,033,248	9,847,040
Taos	630,615	119,931	699,054	1,449,600
Union	3,568,299	....	464,981	4,033,280
Valencia	2,598,856	401,302	2,231,720	5,231,880
Total	55,534,724	6,385,181	16,454,495	78,374,400

COMMISSION OF IRRIGATION.

By sections 62 and 63, chapter 65, laws of 1897 of the New Mexico legislature, approved March 18, 1897, a commission of irrigation and water rights was appointed. At the next session of the legislature, by section 34, chapter 75, laws of 1899, approved March 16, 1899, a commission of irrigation was appointed. By section 15, chapter 49, laws of 1901, approved March 20, 1901, the said section 34 was amended so as to read as follows:

SEC. 34. There is hereby created a commission of irrigation, to consist of five members, to be appointed by the governor, with the advice and consent of the legislative council, to serve for two years and until their successors are appointed. Said commission shall elect from among their members a president and secretary.

It shall be the duty of said commission to investigate and select the most suitable sites for permanent reservoirs for irrigation purposes, and for the improvement of the Rio Grande, and also to designate such tracts of public land, capable of irrigation from such reservoirs, as it would, in their judgment, be advisable to locate and select for the Territory under said act of Congress, in order to secure the benefit of the enhanced value of the lands resulting from the establishment and construction of such reservoirs, for which purposes said commission may employ all necessary expert assistants; and such commission shall notify the commission authorized to select such lands of the location of such reservoir sites and public lands available for irrigation thereunder. And the funds derived from the sale or lease of any lands, donated to the Territory under the act of Congress hereinbefore referred to, for the establishment of permanent reservoirs and the improvement of the Rio Grande, shall be expended or invested by the Territorial treasurer, under the direction of the commissioner of public lands, with the approval of said irrigation commission, for the purpose of aiding and securing the establishment of permanent water reservoirs, as herein or hereafter prescribed by law. Whenever any person, association, or corporation shall have obtained the right to appropriate and acquire the lawful use and ownership of water sufficient for the permanent cultivation and irrigation, by means of reservoirs, of lands belonging to this Territory which may have been selected for the establishment of permanent water reservoirs for irrigating purposes under the act of Congress aforesaid, and shall satisfy the irrigation commission of their good faith and ability to so construct the same if aided and assisted by a contract for the sale of a portion of said lands so belonging to said Territory for said purpose, then it shall be lawful for the commissioner of public lands, with the approval of said irrigation commission, to contract with such person, association, or corporation that in the event of the construction of such reservoir or reservoirs, whereby sufficient water for the permanent irrigation and cultivation of said lands shall be secured, the Territory will pay to such person, association, or corporation so constructing such reservoir or reservoirs, in aid of such construction, and after the same shall have been constructed and completed to the satisfaction of said irrigation commission, such proportion, not exceeding seventy-five per cent, as said board may deem advisable of the proceeds of leases and sales of such of said lands granted and located for reservoir purposes as may be rendered capable of permanent irrigation and cultivation by means of such construction, or which may be necessary for right of way or occupation for such reservoirs and the structures appurtenant thereto, not exceeding fifty thousand acres in all for any one irrigation enterprise and not exceeding in any case the amount of money actually expended for such construction. And upon the due completion of said construction, to be evidenced by a certificate to that effect by the irrigation commission, filed and recorded in the office of the commissioner of public lands, in such form and manner and under such regulations as may be prescribed by said commissioner of public lands, the person, association, or corporation so constructing such reservoir shall be entitled to receive from the Territorial treasurer out of the fund appertaining thereto, upon the warrant of the auditor, such agreed proportion of the proceeds of lands as aforesaid, not exceeding fifty thousand acres for any one enterprise, as in such contract provided, as and when the said proceeds may be realized. Said irrigation commission shall, at least thirty days before the meeting of the legislature, make a report to the governor embracing all available information concerning the best method of improving the Rio Grande, and increasing the surface flow of the water in the bed of the river; also concerning the subject of irrigation and water supply, the quantity of land in the Territory cultivated by means of irrigation, the extent of the present and proposed system of storage reservoirs, the conditions existing in different parts of the Territory with reference to irrigation and water rights, and such other facts as they may deem proper, together with recommendations as to needed legislation on any of such subjects. The members of said irrigation commission shall each be entitled to a compensation of five dollars per day for each day actually necessary to perform the duties herein required, not exceeding twenty days in any one year, and their necessary expenses, as a compensation for the services herein required to be performed by them. All expenses incurred by the commission, to be certified by the secretary thereof and approved by the president, shall be paid out of the proceeds of the land leased and sold under this act which are credited to the fund for the establishment of permanent reservoirs for irrigating purposes and the improvement of the Rio Grande.

NORTH DAKOTA.

The amount of vacant public land in North Dakota June 30, 1901, is shown by the table below. A summary of the conditions by States on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in North Dakota on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Barnes	8,040	53,760	902,040	963,840
Benson	37,300	228,380	617,520	883,200
Billings	3,362,633	172,000	401,367	3,936,000
Bottineau			727,680	727,680
Burleigh	241,860		833,340	1,075,200
Cass		72,720	1,048,560	1,121,280
Cavalier	11,660	127,040	828,980	967,680
Dickey	55,240	40,960	637,240	733,440
Eddy	19,920	42,520	352,280	414,720
Emmons	287,130		704,870	992,000
Foster	3,700	19,200	387,340	410,240
Grand Forks	4,460	48,000	864,020	916,480
Griggs	12,900	25,600	428,700	467,200
Kidder	242,520		652,200	894,720
Lamoure	8,120	40,960	685,640	734,720
Logan	225,660		401,540	627,200
McHenry			939,520	939,520
McIntosh	183,290		456,710	640,000
McLean	1,292,220	223,920	626,580	2,142,720
Mercer	904,315	82,000	248,885	1,235,200
Morton	1,315,984	930,000	787,616	3,033,600
Nelson	800	50,000	582,800	633,600
Oliver	170,560		294,720	465,280
Pembina	240	42,000	683,520	725,760
Pierce	65,120	38,390	541,610	645,120
Ramsey	16,000	71,130	680,870	768,000

Unappropriated, reserved, and appropriated lands in North Dakota, etc.—Continued.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Ransom	4,260	30,720	517,980	552,960
Richland		48,640	876,160	924,800
Rolette	35,720	81,280	486,520	603,520
Sargent	2,760	30,720	519,480	552,960
Stark	2,873,759	92,800	874,721	3,841,280
Steele		27,050	433,750	460,800
Stutsman	354,660	51,200	1,063,580	1,469,440
Towner	8,720	39,960	622,040	670,720
Traill	4,080	32,000	522,000	558,080
Walsh	11,520	48,721	776,879	837,120
Ward	3,321,468	295,140	664,992	4,281,600
Wells	152,050	15,040	662,350	829,440
Williams	2,065,022	145,000	37,658	2,247,680
Total	17,303,691	3,246,851	24,374,258	44,924,800

In North Dakota irrigation has not played a conspicuous part. The eastern part of the State is humid or subhumid, and the western unsettled portion reaches into the borders of the arid region. Farming is carried on extensively east of Missouri River, crops being usually successful, the percentages of failure increasing toward the western part of the State. Beyond Missouri River the country is at present devoted mainly to stock raising. There are a number of valleys where irrigation is practiced in a small way, and where by means of water storage it can be increased as necessity arises.

The largest source of water supply is Missouri River. This is bounded throughout most of its course by bluffs, at the foot of which are occasional fringing valley lands. Most of these lands are sufficiently humid to produce fair crops, and irrigation has not been absolutely essential. The diversion of water from the Missouri, in a small way at least, is practically impossible, since the fall of the river is very little, being less than that of the ordinary irrigating canal.

To divert water from Missouri River a gravity canal must head in Montana, where the grade of the river is greater than in North Dakota. A preliminary survey has been made, showing that such diversion on the north side of the river might possibly be made to reach some of the lands along the stream, but would be very expensive; a detailed survey must be made to settle the fact.

While the Missouri may possibly not be utilized by gravity, it is believed that some of its waters can be employed advantageously by means of pumping. There are throughout North Dakota vast areas of impure coal, or lignite; it may be feasible to utilize this lignite in the creation of cheap power to be used in pumping the waters of Missouri River on a large scale. This matter is under investigation, preliminary work being begun during the summer of 1902.

The total area irrigated in North Dakota in 1899 was 4,872 acres, only 57 acres of which are reported as being watered by means of wells. In 1889 there were irrigated in all only 445 acres. Settlement is rapidly increasing in the western or arid portion of the State, and there has been a succession of years favorable to agriculture, so that the newcomers are encouraged in their efforts. If, however, these years should be exceptional as regards the amount of moisture available, there will result, as in western Kansas and Nebraska, great suffering and hardship from the failure of crops. It will be remembered that in these States a wave of settlement advanced toward the West during the periods of unusual summer rains, and retreated, with great disaster to individuals, following the return to normal climatic conditions. Thus it is in western North Dakota; while at present the settlers, inexperienced in irrigation, do not appreciate its necessity, later there may be an urgent demand for its speedy introduction. The way in which this can be done successfully is not at first obvious, and will require very careful consideration of methods and cost.

OKLAHOMA.

The amount of vacant land on June 30, 1901, is shown by the table below. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in Oklahoma on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Beaver	3,160,655		512,305	3,672,960
Blaine	19,240	282,040	300,960	602,240
Canadian		213,700	300,220	513,920
Cleveland	800	80,000	268,000	348,800
Custer		132,560	508,080	640,640
Day	333,536	38,400	296,224	668,160
Dewey	24,187	108,320	512,613	645,120
Garfield	55,040	74,462	565,538	695,040
Grant		46,855	595,705	642,560
Greer	243,267	7,841	1,280,412	1,531,520
I		650,240		650,240
Kansas Nation		99,200		99,200

Unappropriated, reserved, and appropriated lands in Oklahoma, etc.—Continued.

County	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Kay	100,800	46,579	425,421	572,800
Kingfisher	2,783	74,240	493,217	570,240
Kiowa and Comanche Reservation		2,971,520		2,971,520
Lincoln		170,774	444,266	615,040
Logan	7,360	23,294	448,706	479,360
Noble			403,840	403,840
Oklahoma		30,440	425,880	456,320
Osage Nation		1,470,720		1,470,720
Pawnee	13,938	30,949	301,993	346,880
Payne	1,760	66,836	417,164	485,760
Pottawatomie	4,600	273,900	227,100	505,600
Roger Mills	135,213	52,160	574,867	762,240
Washita	5,900	109,000	517,420	632,320
Woods	76,914		1,682,446	1,759,360
Woodward	711,385	1,680	1,395,735	2,108,800
Total	4,897,378	7,055,710	12,898,112	24,851,200

In this Territory settlement has progressed with wonderful rapidity, and the public lands, except in the western prolongation known as Beaver County, have nearly all passed into the hands of individuals. Crops are raised throughout the Territory without irrigation, even in the western portion adjacent to the panhandle of Texas certain drought-resisting crops being successful each year. In 1899 only 2,759 acres were irrigated, mainly in Beaver and Woodward counties.

A considerable part of the Territory lies within the Red Beds region, where gypsum is abundant, and there the waters are consequently so heavily charged with mineral water that it is doubtful whether they can be successfully used in irrigation. The principal streams flow with gentle fall in broad, sandy channels, dry throughout the summer season. Water can not be easily diverted by gravity ditches, and the construction of dams across the streams involves serious engineering problems.

One of the most important matters in connection with the development of Oklahoma is to ascertain the character of the waters which can be obtained from wells, utilizing the localities where the water is not heavily charged with mineral matter, and ascertaining whether artesian conditions exist. It is probable that pumping may be resorted to over some portion of the Territory to provide water for scattered areas cultivated by irrigation.

WICHITA MOUNTAIN PROJECTS.[a]

In the southern part of the Territory are the Wichita Mountains, granite hills from which the Red Beds have been largely removed. From this crystalline area small streams of pure water issue, and it is probable that these can be successfully used in irrigation. Already several projects have been planned by corporations and individuals. Nearly all of the land to be irrigated is in the hands of settlers, and so far as can be learned, there are no considerable tracts of Government land which can be reclaimed, excepting an area of about 400,000 acres now held as an Indian pasture.

In the latter part of 1902 an examination was made by Mr. Bailey Willis, of the United States Geological Survey, extending from Lawton, Okla., up the valley of Medicine Bluff Creek and across the Wichita Mountains to Mountain Park, and thence northwest across and along the valley of Red River to Granite. The topographic conditions in this area are peculiarly favorable for reservoir purposes, but among the numerous instances three deserve special note. In the order in which they were visited they occur, first, on Medicine Bluff Creek, in sec. 7, T. 3 N., R. 12 W.; second, in secs. 3, 4, 9, and 10, T. 3 N., R. 17 W.; and third, in sec. 22, T. 5 N., R. 20 W. A brief description of each of these situations follows:

MEDICINE BLUFF SITE.

In sec. 7, T. 3 N., R. 12 W., the valley of Medicine Bluff Creek is an extensive bottom land, approximately from 1 to 1½ miles wide 60 feet above the stream level. The stream itself has moderate fall. Near the south line of the section the valley narrows to a canyon 75 feet deep and 400 feet wide, between steep walls. Beneath the wider valley the rock is rather impervious red shale and sandstone; in the canyon it is granite, more or less jointed, but forming a fairly solid mass, suitable for the foundations of the dam. The stream in the canyon runs on bed rock.

The drainage area tributary to this site is estimated from the map at about 90 square miles. The waters from the reservoir might be conveyed, in a distance of 10 miles, down the valley to Fort Sill and thence over the prairie lands in the vicinity of Lawton. The height of the dam site above Lawton is 200 feet, and the water would be available upon the highest prairies of the neighborhood.

The value of this reservoir site is limited by the small area tributary to it. Medicine Bluff Creek has the reputation of being a comparatively constant stream, for that region; but from field observation, without measurement, it would appear probable that the greater part of its flow throughout the year could be stored without utilizing the entire capacity of the reservoir site.

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[a] From report of Bailey Willis.

The waters of Medicine Bluff Creek flow largely from granite slopes, and so far as they are derived from other rocks are not contaminated by gypsum or alkali.

LOWER NARROWS OF OTTER CREEK.

In sec. 9, T. 3 N., R. 17 W., several branches of Otter Creek assemble in an unusually flat valley, and the combined stream enters a canyon about 200 feet wide and approximately 100 feet deep, with nearly vertical walls. The conditions are the same as those already described on Medicine Bluff, except that the valley above the canyon is much broader and shallower and the canyon is narrower. It is estimated from the map that the drainage area of Otter Creek tributary to this reservoir site is about 125 square miles. Surveys have been made by the Otter Creek Irrigation Company on the basis of a dam 60 feet in height, constructed to throw the water over the lowest point in the divide to the southeast, and according to Mr. Mark Roberts, the originator of the plan, the area included within the contour at the level of the top of the 60-foot dam is 6,000 acres and the average depth of water in the reservoir would be about 20 feet. Aneroid readings appear to agree fairly well with Mr. Roberts's statements of the position of the outline of the reservoir, at least along the route by which it was crossed.

The area to be irrigated by the water which may thus be stored lies south of Mountain Park, on the lower course of Otter Creek and along Red River. The area of agricultural lands available is probably more than can be supplied by the drainage basin, which it is proposed to utilize, and the capacity of the reservoir also is probably sufficient to hold all the water that can be stored from that basin.

The waters of Otter Creek flow in part from hills of igneous rock, but in greater part from areas of the Red Beds. They do not, however, contain any notable quantity of gypsum or alkali.

QUARTZ MOUNTAIN SITE, NORTH FORK OF RED RIVER.

North Fork of Red River is joined in T. 5 N., R. 20 W., by a very considerable stream, known as Elm Fork, the waters of which contain a large amount of gypsum and probably of other salts. Any irrigation plan contemplating the use of the waters of North Fork of Red River should exclude those of Elm Fork on this account. Above its junction with Elm Fork, North Fork of Red River flows from a valley in the Red Beds across a small area of granite in the east end of Quartz Mountain. The narrowest point of the short canyon which is thus formed is in the eastern part of sec. 22, T. 5 N., R. 20 W., and the wider valley above the canyon occupies sections 14 and 15. The canyon has a minimum width at water level of 500 feet. The depth to granite in the bottom land is indeterminate. Fence posts are sunk in red and green clays of the Red Beds just below the narrowest part, and it may be inferred that the granite is not near the surface, even at the dam site; but the shales and sandstones of the Red Beds would probably afford an equally substantial foundation. It was stated that even when the river bed is otherwise dry there is always a pool of water next to the granite at the dam site, and this would seem to indicate that the underflow was brought to the surface by ledges of rock. About 200 yards west of the canyon there is a depression in the granite ridge 80 feet above the river, and this would limit the depth of the reservoir, unless a supplementary dam were placed in that gap. The gap is narrow, and could easily be controlled, either by closing it with the dam or by utilizing it as a waste weir. A dam 80 feet high would back the water up the valley of Red River for many miles, and would constitute a reservoir of very large proportions. The foundations and walls at the dam site appear to be adequate for any such construction.

The drainage basin of Red River tributary to this site is roughly estimated at 3,000 square miles. The quality of water, even in the autumn season, is good, although slightly saline to the taste.

The water from this site could most easily be conducted across Elm Fork and southwestward into Greer County. The Otter Creek Irrigation Company proposes, however, to divert at least the flood waters to a canal extending east from the above-described dam site to Tepee Creek, and thence across Elk Creek, by a deep cut in the divide, to the basin of Otter Creek. Surveys for this purpose were contemplated late in October.

NORTHERN STREAMS.

The reservoir sites just described all occur in the southern part of the Territory on comparatively small streams. The larger rivers which traverse the northern portion of the Territory present very different aspects. They are the Washita, the South Canadian, the North Canadian, the Cimarron, and the Arkansas, which flow in strikingly parallel courses but a few miles apart.

Washita River.—This river was examined at Washita Junction, Custer County. It is there a clear stream, with heavily timbered bottom land composed apparently of rich alluvium. A large growth of cottonwoods, elms, and walnuts gave the bottoms an appearance such as one sees in Ohio, which is quite unusual so far west. Prof. Charles N. Gould states that this character distinguishes the Washita among the streams of Oklahoma, and it is probable that it has something to do with the rocks of its drainage basin, which apparently consist of materials that yield a good loam. One of the principal gypsum ledges of Oklahoma stretches along its course from southeastern Day County, through Custer and Washita counties, into Caddo County. The waters are probably saline.

South Canadian River.—This has a very peculiar regimen, being subject to sudden and unforeseen floods not apparently connected with current meteorologic conditions in its drainage area. The channel of the stream is known to be excavated to a considerable depth, probably more than 100 feet, below the present river bed, and is filled with sand. The peculiar floods may possibly be due to the rise of underflow to the surface, as a late result of previous irregular supply.

North Canadian River.—The North Canadian has a very narrow drainage basin and is fed chiefly by springs flowing from the Tertiary sands which cap the High Plains in the northwestern part of the Territory. The waters are peculiarly free from saline impurities, and the stream is said to have an unusually constant flow. As in the case of the South Canadian, there is an ancient channel deeply filled with sand, and the bottom lands are very extensive. In the vicinity of Geary, Blaine County, the valley presents some of the finest farming lands in the Territory. From 8 to 10 miles north, up the valley, are the Red Hills and the Stony Hills, whose relations on the map suggest that possibly there might be a chance to control the stream; but at this point the bottoms are more than a mile in width, and there is no foundation suitable for a dam.

Other sources of water supply.—The principal streams in the extreme northern part of the Territory are the Cimarron and the Arkansas. These flow usually through broad valleys, and have such gentle fall that the water can not be easily diverted. The channels are in most places very broad and sandy, the water in flood filling these from bank to bank, and at other times crossing and recrossing and dividing into a number of threads. In general it may be said that apart from the reservoir sites in the Wichita Mountains there are few opportunities favorable for the storage of large bodies of water in Oklahoma. The valleys are wide, the slopes are gentle, and the stream channels are filled to great depth with loose sand which conveys a very copious underflow. Floods occur suddenly, are of large volume, and brief in duration. The topographic relations present one peculiarity which might be important in irrigation work: All of the larger streams occupy the northeastern side of their drainage basins, and their tributaries enter from the southwest. The southwestern or right-hand slopes of the valleys are cut into canyons, mesas, and ridges. The northeastern valley slopes are correspondingly smooth, and the ascent from the river to the divide correspondingly short and steeper. This condition of the right-hand slope on the larger streams appeared to be favorable to the establishment of numerous small reservoirs calculated to catch flood waters at many points, possibly by the aid of wing dams. The incessant wind forcibly suggests to anyone in the region the availability of that power as an aid to irrigation.

Cimarron River.[a]—The Territory of Oklahoma has a narrow prolongation separating the panhandle of Texas from Kansas and Colorado, this area being known as Beaver County. The greater part of this consists of vacant public land. Cimarron River flows into the western end of Beaver County and continues easterly, turning toward the north, passing into Kansas, and then returning to Oklahoma. The lands along this stream have been taken up largely by settlers and a small area has been irrigated.

The principal irrigation development in this part of the country has been carried on by C. D. Perry, of Englewood, Kans. About fourteen years ago he constructed a ditch from the Cimarron River to irrigate his lands lying in Kansas. He built a sheet pile dam across the channel, consisting of 2-inch piling driven to a depth of about 12 feet into the sand. The tops were held in line by two walings fastened with three-eighth inch bolts through the piling and both strips. This ditch was about 8¼ miles long, and had a capacity of approximately 14 second-feet. It was not well built and was difficult to maintain. The total cost was nearly $10,000. The floods tore out a considerable portion of the dam, filled the channel with sand, and made a new channel, passing around the remains of the dam.

A new ditch was built by Mr. Perry, with headgates lower down the stream. Instead of a dam for diverting the water he constructed a wooden stave pipe, 30 inches in diameter, sunk in the sand, extending from the headworks diagonally upstream. This was 900 feet long and was planned to extend a mile or more. The under side of the pipe had perforations through galvanized sheet iron, intended to admit the water. The pipe was partly washed out before it was tested and the remaining portion filled with sand. Water is obtained, however, through a ditch heading at a brush dam below the pipe. The ditch now in operation is 7 miles long, and cost nearly $3,000, including the wooden stave pipe; it is successful, and discharges at the lower end into the old ditch. Experiments for obtaining the so-called underflow could probably be made at this locality with good chances of success.

A suggested opportunity for construction of storage works has been pointed out in sec. 32, T. 5 N., R. 6 E., of the Cimarron meridian. The river at this point passes a bluff 30 feet or more high. To the south the overflowed bottom is about one-half mile wide, and to the north the ground rises gradually for a quarter of a mile before gaining the height of the south bluff. A dam 30 feet above the river would measure one-half mile in length, and one-fourth mile additional would be required to complete it on the north slope. The bottom lands increase in width above the dam site, and the fall of the river being approximately 8 feet to the mile, it is estimated that a reservoir could be created about 3.5 miles long by a mile wide, having a capacity in round numbers of 35,000 acre-feet. A survey has not been made, but these figures are given from inspection of the ground. It is believed that the flow of Cimarron River is sufficient to fill this reservoir. Below it are lands situated on both sides of the river. It is claimed that there is an impervious clay lying only a few feet below the bed of the river upon which a dam could be founded. A structure placed at this point must be built presumably of earth, as there is little rock in sight. On the tops of the bluffs, about 300 feet above the river, are fragments of a porous limestone, which may be used in concrete or for revetment on the slopes.

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[a] From report of W. G. Russell.

The construction of a dam across the Cimarron, in Beaver County, is a difficult undertaking and one which must be given careful consideration. Little can be known without expensive surveys and borings to ascertain the character of the foundations and the proper material to be used in the structure.

OREGON.

The recent rapid disposal of public lands in this State has rendered available a large amount of money for the reclamation fund, the State standing third in order of income. On the other hand, the demands and immediate necessities of reclamation work are not particularly noticeable. There is a large extent of vacant public land, most of it being east of the Cascade Mountains. The total area vacant is, in round numbers, 33,000,000 acres, or over 63 per cent of the land surface of the State. The opportunities for reclaiming some of this land are good, particularly along the foot of the Cascade Mountains, from which issue a number of important streams.

Oregon was one of the last States to adopt the provisions of what is known as the "Carey Act," and public attention has only recently been drawn to the opportunities apparently offered in this State. There has been considerable activity displayed in selecting lands which may be irrigated, and several lists of State locations have been made, including localities where water can be most advantageously used. Pending the consideration of these lists and the completion of plans by the State for reclamation of desert land, there is some uncertainty as to what may be the best opportunities for complete reclamation systems.

In the northeastern portion of Oregon are the Blue Mountains, from which issue a number of streams, some of which can be used in the reclamation of arid lands. Notable among these is Silvies River, which flows southerly into Malheur Lake. Storage reservoir sites are said to exist upon this stream. The lands to be irrigated are, however, almost completely in the hands of individuals and cattle companies. Toward the north and northeast are other important streams, many of them small, but deserving of careful examination.

South of the Blue Mountains are the broad, lava-covered plains, upon which grazing is excellent, and where the land is almost completely in the hands of the National Government. Here artesian water can possibly be had. A systematic study of this area was begun by Prof. Israel C. Russell and carried on during the summer of 1902.

In the southern part of the State, adjacent to California, in Lake and Klamath counties, are a number of bodies of water which may be utilized in the irrigation of meadow lands. These, however, are almost completely in the possession of individuals, and reclamation will necessitate not only a very careful consideration of methods of storing and distributing water, but also the question of acquiring private lands in order to reclaim and dispose of them. In short, the larger and most obvious localities where reclamation work can proceed with the greatest advantage have already been selected by the State, and it is not desirable to forestall State action in the matter. The preliminary examinations made so far show that most of the reclaimable land is so situated that the projects must be small and scattered and that little vacant public land can be benefited. Further examination will doubtless reveal many localities where work can be begun to advantage, and persistent

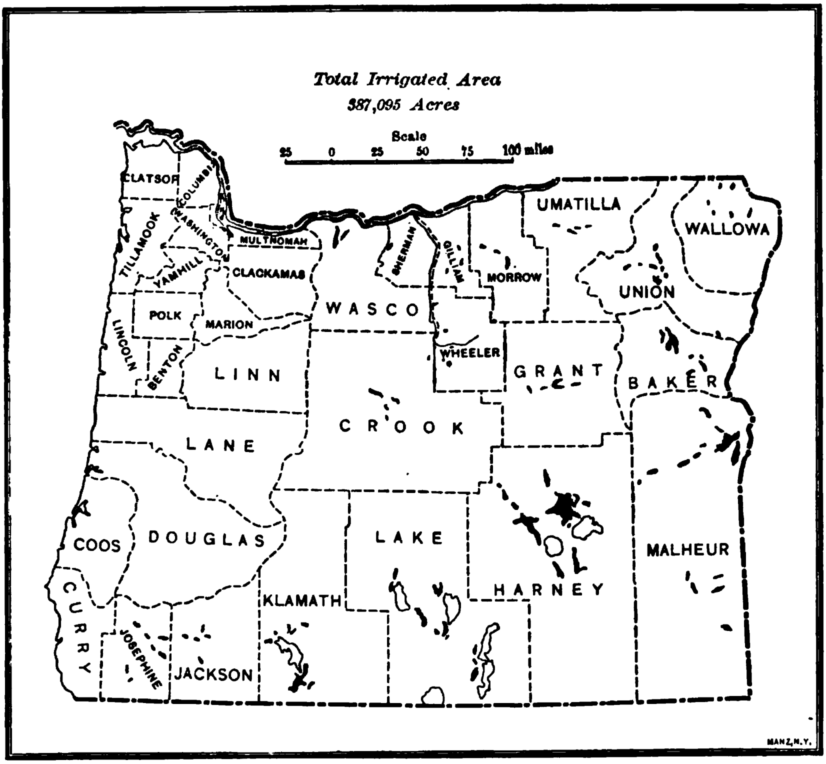

FIG. 58.—Map of irrigated areas in Oregon.

search will doubtless justify the expenditure of considerable sums in construction of storage and diversion works.

The area irrigated in Oregon, as shown by the census of 1899, was 387,095 acres. Ten years earlier only 177,944 acres were irrigated. There has been a notable increase in acreage watered, but the number of irrigators has not been added to in the same proportion. In other words, the size of irrigated farms has shown a notable enlargement. This is contrary to the conditions in most of the States. This abnormal increase in acreage is probably due to the reporting as irrigated the meadows or swamp lands in central Oregon, which are alternately drained and flooded for the production of natural hay. There are extensive tracts of lowland, which under the "swamp act" were donated to the State, and which have subsequently passed into the hands of cattlemen. By controlling the water supply of these lands by means of cheap and easily built structures, the spring floods can be turned upon the meadows and the excess of water drawn off later in the season, resulting in a large yield of wild hay. These lands are reported as being irrigated, although the artificial control of water is of the most inexpensive character.

The table below shows the amount of vacant public land on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office will be found on page 19.

Unappropriated, reserved, and appropriated lands in Oregon on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Baker	962,363	....	493,637	1,456,000
Benton	27,305	10,880	395,095	433,280
Clackamas	307,565	309,812	573,663	1,191,040
Clatsop	22,546	800	501,454	524,800
Columbia	3,458	....	429,822	433,280
Coos	118,374	8,699	882,847	1,009,920
Crook	3,155,240	968,669	839,931	4,963,840
Curry	660,598	....	269,962	930,560
Douglas	610,413	642,340	1,858,287	3,111,040
Gilliam	322,207	....	396,513	718,720
Grant	2,206,087	7,123	705,190	2,918,400
Harney	5,349,722	....	1,041,318	6,391,040
Jackson	384,765	245,685	1,110,990	1,741,440
Josephine	754,518	....	323,242	1,077,760
Klamath	1,690,103	1,207,679	848,779	3,746,560
Lake	4,164,863	137,000	711,897	5,013,760

Unappropriated, reserved, and appropriated lands in Oregon, etc.—Continued.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Lane	553, 053	897, 395	1, 352, 752	2, 803, 200
Lincoln	194, 021	168, 000	283, 099	645, 120
Linn	206, 177	372, 240	900, 623	1, 479, 040
Malheur	5, 693, 902	1, 130	566, 728	6, 261, 760
Marion	134, 494	105, 860	508, 446	748, 800
Morrow	236, 438	....	1, 057, 002	1, 293, 440
Multnomah	2, 415	40, 934	231, 211	274, 560
Polk	22, 230	24, 920	401, 490	448, 640
Sherman	2, 547	25, 600	442, 893	471, 040
Tillamook	401, 219	....	314, 941	716, 160
Umatilla	772, 109	151, 360	1, 070, 771	1, 994, 240
Union	1, 258, 250	....	755, 190	2, 013, 440
Wallowa	1, 339, 291	....	442, 469	1, 781, 760
Wasco	582, 022	132, 370	1, 181, 288	1, 895, 680
Washington	73, 600	....	384, 000	457, 600
Wheeler	746, 338	29, 529	341, 573	1, 117, 440
Yamhill	66, 759	12, 796	375, 485	455, 040
Total	33, 024, 992	5, 500, 821	21, 992, 587	60, 518, 400

SOUTH DAKOTA.

The table below shows the area of vacant lands on June 30, 1901. A summary of the conditions by States on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in South Dakota.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Armstrong	....	934, 400	....	934, 400
Aurora	80	....	463, 280	463, 360
Beadle	7, 763	....	805, 037	812, 800
Bonhomme	....	....	364, 160	364, 160
Boreman	....	787, 840	....	787, 840
Brookings	....	....	522, 880	522, 880
Brown	22, 280	60, 110	1, 034, 410	1, 116, 800
Brule	....	....	517, 120	517, 120

Unappropriated, reserved, and appropriated lands in South Dakota—Continued.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Buffalo	800	163,000	145,320	309,120
Butte	4,504,707		509,053	5,013,760
Campbell	55,000	36,720	397,880	489,600
Charles Mix	12,720		706,000	718,720
Clark	12,720		610,000	622,720
Clay	7,176		253,944	261,120
Codington	73,380		429,660	503,040
Custer	451,692	339,840	240,148	1,031,680
Davison			311,040	311,040
Day	19,665		669,615	689,280
Deuel			397,440	397,440
Dewey		1,420,160		1,420,160
Douglas			284,800	284,800
Edmunds	36,810	43,200	672,630	752,640
Fall River	713,318		411,162	1,124,480
Faulk	2,916		643,484	646,400
Grant			444,160	444,160
Gregory	16,830	496,957	128,773	642,560
Hamlin			347,520	347,520
Hand			907,520	907,520
Hanson			311,040	311,040
Hughes	88,031	91,539	310,030	489,600
Hutchinson			522,880	522,880
Hyde	47,272	54,720	458,008	560,000
Jerauld	5,040		345,680	350,720
Kingsbury			533,760	533,760
Lake			351,360	351,360
Lawrence	7,546	330,240	183,174	520,960
Lincoln			370,560	370,560
Lugenbeel		682,240		682,240
Lyman	1,636,348	355,000	240,492	2,211,840
McCook	2		367,998	368,000
McPherson	32,310	40,482	660,648	733,440
Marshall	6,145		557,055	563,200
Meade	1,229,726	50,395	641,799	1,921,920
Meyer		900,480		900,480
Miner			364,160	364,160
Minnehaha			513,280	513,280
Moody			330,880	330,880
Pennington	765,463	453,120	442,857	1,661,440

Unappropriated, reserved, and appropriated lands in South Dakota—Continued.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Potter	40,757		535,243	576,000
Roberts	14,112		691,168	705,280
Sanborn			368,640	368,640
Schnasse		1,000,320		1,000,320
Shannon		682,240		682,240
Spink	9,785		961,735	971,520
Stanley	2,668,696	140,538	315,246	3,124,480
Sully	21,086		652,194	673,280
Tripp		947,200		947,200
Turner			399,360	399,360
Union			286,080	286,080
Walworth	43,620	26,240	406,940	476,800
Washabaugh		785,920		785,920
Washington	274,244	704,000	7,356	985,600
Yankton	628		328,972	329,600
Unorganized territory		172,800		172,800
Total	12,828,668	11,699,701	24,655,631	49,184,000

In this State settlement has proceeded both from the east and from the west. From the east there has been the rapid progress of prairie farming, such as that which extended from the Mississippi Valley into and almost across Kansas and Nebraska. Practically all of the land in South Dakota east of Missouri River has been taken up and utilized for farms, crops being successfully raised in moist years.

On the extreme west are the Black Hills, noted for their mineral wealth. As an incident to mining, settlement has taken place in and around the hills, and agriculture by irrigation has gradually spread upward along the more important streams. East of the Black Hills and extending to Missouri River is a vast extent of vacant land of value chiefly for grazing. Much of the area is still held as Indian reservations, and some of it is so greatly eroded into "bad lands" as to be almost worthless.

The chief opportunities for reclamation come from water storage in or adjacent to the Black Hills. The Missouri itself can probably not be used, unless some of its waters are raised by pumping. The tributaries of the Missouri from the west, heading in the Black Hills, have along a portion of their courses some lands which may ultimately be utilized.

In the eastern part of the State is James, or Dakota, River, which flows south through a broad valley and enters the Missouri near the town of Yankton. This stream is too small and sluggish to be utilized for irrigation, but the area drained by it has been found to be underlain by pervious rocks whose structure is such as to yield artesian water. The flow of some of the wells of this valley is notably large. Tracts of considerable size have been cultivated by irrigation from these wells. The water is frequently charged with mineral matter, so that usually great care must be taken in applying it. The total area irrigated in South Dakota in 1899 was 43,676 acres, the greater portion being in the counties adjacent to the Black Hills. Of this total area 5,223 acres were irrigated from wells. The greater part of the land under irrigation is devoted to hay and forage.

Examinations have been begun of the opportunities for further development of the artesian area, particularly in the region east of the Black Hills. The largest acreage of arid land can, however, probably be reclaimed by stored waters. The localities where water can be held in considerable quantities are not obvious, but it is known that there are a large number of small reservoir sites widely scattered. The systematic examination of these is essential to the consideration of the general plans for reclamation.

UTAH.

In Utah the water supply is widely distributed, mainly in small streams which flow from steep mountains upon broad valleys. At the mouth of the canyon from which each stream issues settlements have been made, and the entire flow of each stream utilized in irrigating the adjacent fields. As population has increased, the methods of distributing and using the water have improved, larger and larger areas being brought under irrigation. The spring floods are utilized as far as possible in wetting the ground, but some water escapes, as storage reservoirs have not yet been extensively employed. The larger rivers of the State, such as the Bear on the north, the Green on the east, and the Sevier in the center, discharge, especially in the spring, great volumes of water which go to waste. These rivers offer the principal opportunities for the construction of large works of reclamation.

The total area irrigated in Utah in 1899 was 629,293 acres, the lands being scattered mainly through the central part of the State, particularly in the northern end. The farm area is small and, as a rule, carefully cultivated. The largest crop acreage is in alfalfa, next to this coming wheat. Orchards, small fruits, and sugar beets are also important. The most valuable lands are those located in the valleys of Utah Lake and Great Salt Lake, the waters for irrigation of these coming from the Wasatch Mountains on the east and flowing into Utah Lake or into its outlet, Jordan River.

The table below shows the amount of vacant land in Utah on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office will be found on page 19.

Unappropriated, reserved, and appropriated lands in Utah on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Beaver	1,591,595	....	59,605	1,651,200
Boxelder	2,496,768	347,132	635,140	3,479,040
Cache	318,289	89,483	348,068	755,840
Carbon	931,628	....	89,812	1,021,440
Davis	49,645	....	132,755	182,400
Emery	2,651,123	....	123,917	2,775,040
Garfield	3,199,744	13,786	52,390	3,265,920
Grand	2,392,540	....	13,220	2,405,760
Iron	1,917,419	....	184,341	2,101,760
Juab	1,961,842	13,900	136,258	2,112,000
Kane	2,754,829	....	40,691	2,795,520
Millard	4,042,459	15,020	207,481	4,264,960
Morgan	175,650	35,844	171,866	383,360
Piute	418,219	7,850	50,091	476,160
Rich	424,855	53,623	193,522	672,000
Salt Lake	135,424	24,987	331,109	491,520
San Juan	4,598,870	522,240	14,890	5,136,000
Sanpete	665,906	16,800	316,334	999,040
Sevier	1,005,510	67,929	129,761	1,203,200
Summit	466,301	445,111	328,268	1,239,680
Tooele	4,219,330	6,412	190,898	4,416,640
Uinta	1,613,103	1,579,646	128,851	3,321,600
Utah	837,225	192,425	329,070	1,358,720
Wasatch	564,130	1,986,560	103,390	2,654,080
Washington	1,529,694	....	42,786	1,572,480
Wayne	1,470,113	680	47,287	1,518,080
Weber	143,804	68,240	136,116	348,160
Total	42,576,015	5,487,668	4,537,917	52,601,600

UTAH LAKE REGULATION.

The most important project for the development of the arid lands of Utah is that which involves the complete control of the water entering Utah Lake or Jordan River. The situation is peculiar, but the engineering features are not especially difficult. The complications arising from vested rights will cause the greatest delay.

Utah Lake occupies the lowest part of the valley included within Utah County. Its principal tributary is Provo River. The waters of this stream and those of Spanish Fork, American Fork, and other creeks are used on the lands bordering the lake, the excess disappearing into the marshes or flowing through channels into the lake. This is a very broad, shallow body of water, from which evaporation is so great that probably more water disappears into the air than is put to beneficial use. It is not economical as a reservoir, and its value could be increased by decreasing its area if, at the same time, the storage capacity could be maintained by providing for a greater annual rise and fall of the diminished surface. It is to the advantage of Utah County to decrease the area of the lake, as by so doing the broad extent of the marsh land would be reduced and the cultivated areas

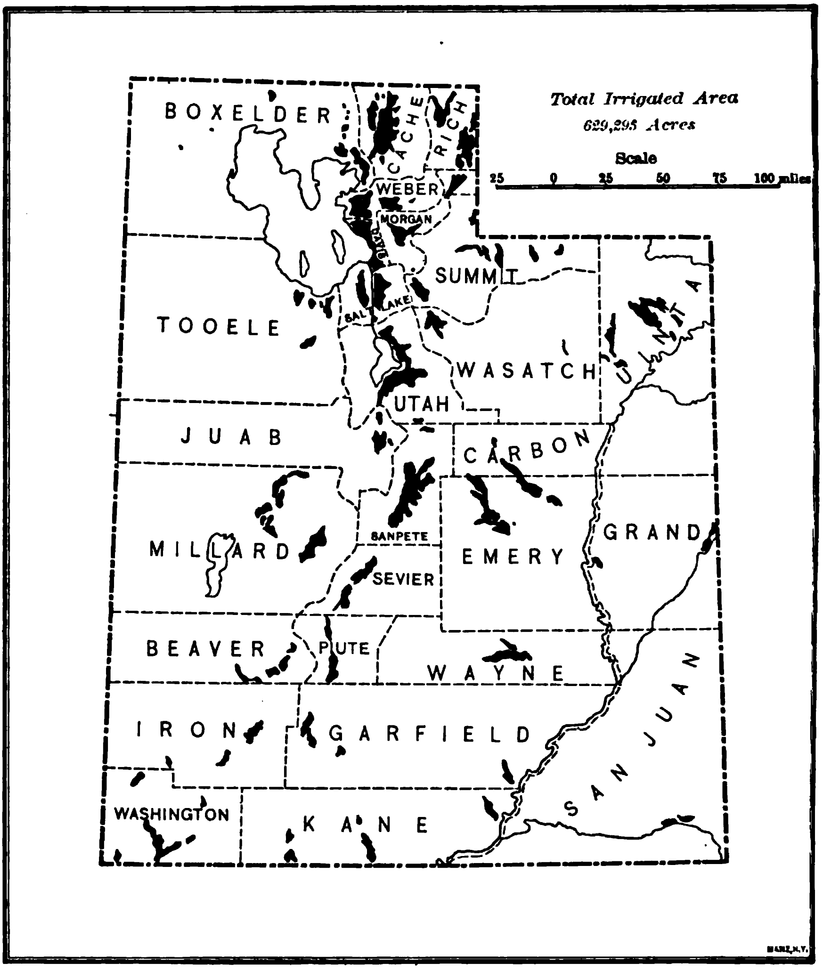

FIG. 59.—Map of irrigated areas in Utah.

extended. By storing all of the water possible in mountain valleys and keeping it from reaching Utah Lake until the time of the year when it is needed, a double benefit would result to Utah County, in making available a larger summer flow of the streams and in keeping to the minimum the area of flooded valley land.

Jordan River, the outlet of Utah Lake, flows toward the north and passes into Salt Lake County. Here it is diverted by a number of canals extending out on both sides of the river, those on the east watering land in the vicinity of the city of Salt Lake. The canal companies taking water from Jordan River desire to maintain Utah Lake at a high level in order to be able to receive water into their canals. Thus controversies have arisen between the two counties, the matter being adjusted by arbitration, settling the height to which Utah Lake could be raised. This agreement has not proved satisfactory in all respects, and it is believed that by a more careful study of the matter the great waste of water which now occurs could be prevented, and that by building storage works in the mountains, reducing the area of Utah Lake, more land can be cultivated both in Utah County and in Salt Lake County. To bring this about will necessitate surveys of all possible reservoir sites, and especially of Utah Lake. This survey should determine whether the area of the lake can be reduced by partial drawing down of the water surface and by the construction of levees or dikes, cutting off the marshes and making the lake a compact body of open water. Further than this, the utilization of the water from Utah Lake must be considered, and the engineering work must be supplemented by a complete statement of the use to which the water is now being put and the vested rights involved.

As has been stated, the engineering work in connection with the best utilization of Utah Lake is comparatively simple, but the far more difficult task is that of arranging some scheme by which the vested interests will be harmonized, the rights of all be preserved, and the surplus water made available for disposal, so that the proceeds may repay the cost of the work. The scheme is believed to be feasible, but will necessitate great care, perseverance, and tact on the part of those having it in hand. There is no person more suspicious of change than the irrigation farmer when it comes to matters which touch his water rights. He appreciates that the safety of his home and property is bound up in the title to water, and that any disturbance may result injuriously to him. He knows also that the men who are promoting most of the projects for irrigation are far more shrewd than he; that they employ the best counsel to be had, and that in a contest involving legal questions he will be outwitted. Thus when a community of irrigators is approached with a project, even though it may be to their advantage, the persons having it in hand must make it perfectly plain and bring to bear the strongest arguments.

The situation as regards the more complete use of Utah Lake has been frequently discussed, and at a convention held in Salt Lake City on October 1, 1902, it was urged that this project be given first consideration in the State. As a preliminary to active field work the representatives of the irrigators in Salt Lake County have endeavored to unite on some proposition, and if this can be done and it is apparent that united action will follow it will be desirable to take up the engineering features.

BEAR RIVER PROJECT.

Next in importance to the complete control of Utah Lake is the full utilization of the waters of Bear River. This stream, rising in the high mountains east of Great Salt Lake, flows out of Utah into Wyoming and continues along and near the State line, crossing back and forward between Utah and Wyoming, then passes from Wyoming into the southeast corner of Idaho, where it receives additional water from Bear Lake, the southern end of which is in Utah and the northern in Idaho. Passing out of the marshes at the north end of this lake, Bear River makes a curve toward the south and flows into Utah, and finally empties into Great Salt Lake. Water is taken out of Bear River by a number of canals in the three States above mentioned. The regulation of the river and the best use of its waters involve interstate problems. Studies have been made of the flow of the stream and of the opportunities of storage of the floods. The matter has been quite fully discussed in the annual reports of the Geological Survey, and from the results obtained it is evident that the key to the whole situation may be said to be the control of Bear Lake. In many respects the conditions here are similar to those in Utah Lake drainage basin, the principal exception being that in this case interstate problems must be considered.

In July, 1902, work was begun by Prof. George L. Swendsen, of the agricultural college at Logan, Utah. He has for a number of years been making measurements of discharge, and has also, for private parties, planned or constructed canals leading from the river, thus being thoroughly familiar with the situation. The lands around the lake were reserved from entry in 1892, under the act approved October 2, 1888, as noted on page 451 of the Thirteenth Annual Report of the Geological Survey, Part III. This gives the general location of the lake and the legal subdivisions of the included area. Mr. Swendsen was instructed to look into the matter in some detail, first, with reference to the water supply available for storage; second, the works needed to divert the water into the lake; third, the plans necessary to make the stored water available; fourth, the works necessary to convert the lake into a storage reservoir, and, fifth, other details connected with the successful diversion of the water from the lake.

Bear River flows from Idaho around the point of a ridge or bluff, and then spreads out over nearly level country to the north and east of the lake. Little definite information has been available relative to the spring flow of the river at this point, but it has been estimated to be probably 2,500 second-feet for a period of six weeks in the early spring.

As noted on the maps, Bear River flows through the country to the north and east of the lake, and though Mr. Swendsen had available no definite information relative to the spring discharge of the river, from his own knowledge and that gleaned from old residents he knew it to be rather high, probably 2,500 second-feet for six weeks of the early spring.

This river does not flow into the lake, but there is a channel which drains the lake and empties into the river. The immediate drainage area of the lake affords a small addition to the waters available for storage from Bear River. All of the streams flowing into it or available for storage in the lake were carefully measured and the results are tabulated below:

Results of measurement of streams tributary to Bear Lake.

Stream.	Date.	Volume.
		Sec.-ft.
Bear River	Aug. 16, 1902	159
Do	Aug. 20, 1902	158
Do	Sept. 1, 1902	162
Do	Sept. 13, 1902	187
Bloomington Creek	Sept. 11, 1902	13
St. Charles Creek	do	17
Paris Creek	do	23
Garden Creek	Sept. 14, 1902	12

Available water supply.

Stream.	Mean discharge.		Acre-feet.
	October to April.	April to July.	
Bear River	180	1,630	348,200
Paris Creek	25	40	16,600
Bloomington Creek	15	25	9,900
St. Charles Creek	18	30	11,800
Garden City Creek	10	20	7,200
50 per cent of run-off from drainage basin of lake			65,000
Total			458,700

In the above table is given a summary of the water supply based upon the best information obtainable. The estimated flood discharge is based upon results of measurements farther down the river at Soda Springs and Battle Creek, Idaho. The results for October to April are based upon the measurements of the summer of 1902. During the months of July to October the entire flow of the small creeks is utilized for irrigation, and but a small volume is available from Bear River without interference with the vested rights lower down on the stream. The immediate drainage of the lake is about 250 square miles, upon which the mean annual rainfall is not far from 12 inches Using a run-off factor of 50 per cent, the result of this area is given in the above table.

DIVERSION WORKS.

Having fully determined that the main source of supply was Upper Bear River, Mr. Swendsen began to determine the requirements and possibilities of the diversion works needed to bring the river water into the lake. A line of levels, together with measurements, showed that the distance from the lake to the nearest point on the river where diversion works could be located was 49,700 feet and that the river bed at that point was 54.61 feet higher than the surface of the water in the lake, thus affording an abundance of fall to allow the maximum grade permissible for the canal.

The bed of the river is gravel, but the locality is favorable for the construction of a low concrete dam suitable to control the entire flood discharge of the river. The grade of the canal is planned to be 7.3 feet below high-water line. The preliminary canal line was run on a grade of 1.056 feet per mile, or 0.02 per hundred feet, the elevations having been determined at each 100-foot point, and all horizontal angles carefully read. The classes of material all along the line were noted and probable conditions relative to right of way determined. For the most part the channel will pass through lands where right of way can be secured at a low figure. With few exceptions the line of the canal offers no particular obstacles to construction.

The headworks can be readily installed; the greater part of the channel will be through the most favorable ground for ease of construction, there being necessity for but one drop and no more than 4,000 to 5,000 feet of line where rock work will be encountered, and in this case not of the extremely difficult kind.

Interference with other channels is reduced to a minimum by the location made, and no serious difficulties can arise from that source. The grade of the channel, as located, is 3 feet above the present level of the lake at the point of discharge into the lake. Numerous benches and monuments were placed on or near the line, and described in the field notes. A large number of high stakes were placed on the line, so that for some time, at least, it may be inspected with dispatch.

THE LAKE AS A RESERVOIR.

As noted in the Thirteenth Annual Report, Part III, mentioned above, the contours of the ground around the lake are such that a rise of 3 or 4 feet will not materially affect the surrounding country, and judging from the water marks and statements of residents in the vicinity of the lake, Mr. Swendsen is of the opinion that the present level of the lake is 2 or 3 feet below that of 1887. An examination was made of the north shore, where it was apparent at once that difficulties might arise in retaining flood water. The north shore is formed by a sand bar separating the main lake from the north lake or, as commonly called, Mud Lake. This bar is of considerable width and higher than the usual lake level. It is overgrown with rushes and other vegetation and is used as a highway for travel from one side of the lake to the other. A traverse was made over this portion of the work, and a number of trial pits were dug in different parts of the section to determine the status of the subsurface water and kinds of material. From a study of these, together with other conditions relative to soil and water levels, it is apparent that some work will be needed to make this sand bar sufficiently impervious to prevent the water of the main lake escaping through into Mud Lake. The installation of a cut-off wall or other means of shutting off the leakage is a work of such importance that more detailed study of the materials may be necessary before this feature can be decided upon. This is a vital question in the consideration of the feasibility of the scheme as a whole, and it is believed that the necessary cut-off wall can be put in for such low pressure of water without resort to concrete or other expensive construction. The element of leakage is the only one that can enter the discussion of feasibility and utility of the sand bar as a dike for the proposed storage.

USE OF THE WATER.

There are no lands in the immediate vicinity of the lake that can be benefited by the stored water, and the only outlet from the valley into a locality where benefits are to be derived is through Bear River. Therefore the next problem in the development of the plan was the examination for an outlet from the lake back into Bear River. As stated in the beginning of this report, a channel already drains the lake into Bear River, but it is very small and has such a winding course that it would be inefficient for the purpose desired.

Two plans were considered for this channel: First, there is the possibility of straightening and widening the present channel by the use of dredges or steam shovels floated on barges. The material can readily be moved in that way, but it will amount to about the same as constructing a new channel, the outlet channel making so many detours and sharp turns. The advantage of this plan would also be added to in the questions relative to rights of way. A careful line of levels and measurements of distance from the lake to the river, following as near as possible to the outlet channel, showed the difference in elevation to be 13.47 feet and the distance in a direct line to be 14.5 miles. The levels show that the grade of the country from the lake to the river is practically uniform, and from investigations it is probable that no rock or other hard material will be encountered in the route. The controlling works at the lake can be readily constructed, and probably no overflow dam will be needed, but rather a set of substantial gates set in concrete or masonry.

The second plan examined for an outlet channel was for a canal independent of the present channels. This plan would involve the construction of a channel in very easy country for the most part, though some heavy cuts are involved. This would cross St. Charles, Bloomington, and Paris creeks, but a channel could be constructed to the west of the outlet canal to gather all of the waste water and surplus spring flow from these creeks and divert it into the lake, thus obviating any interference with the outlet channel and at the same time adding to the storage volume. The course would be through meadows and swamp lands the greater part of the way, and the construction would be very simple, though somewhat longer than the canal involved in the first plan. Benches and monuments were carefully established and noted on both these lines, as well as many details of rights of way, quality of materials, etc.

LANDS AVAILABLE FOR RECLAMATION.

In dealing with the questions relating to the disposition of the stored water, it is necessary to mention only the lower limits of the areas available for irrigation and reclamation.

Bear River occupies a unique position in the arid land reclamation of northern Utah and southern Idaho. Already its normal flow in the irrigation months is entirely appropriated, and there yet remains thousands of acres of valuable lands undeveloped and arid, dependent primarily upon Bear River and its tributaries for a water supply. Salt Lake, Weber, Davis, and Boxelder counties, in northern Utah, are all short of water. Boxelder County has thousands of arid acres. Southeastern Idaho has thousands of acres without water. Bear River is a natural source of supply for all these shortages. The expense of development from other sources, such as small reservoirs on small mountain streams, is so great as to make such plans prohibitive, while if the water supply in Bear River can be regulated properly the elevation of the river favors the construction of canals on such a scale as to make reclamation not only possible but profitable.

SUMMARY.

1. Volume of water available for storage estimated at 1,458,000 acre-feet per year.

2. Length of diversion canal from the river to the lake, 9.41 miles.

3. On this diversion canal 3,800 linear feet of rock work and steep sidehill will be encountered. The remainder of the line is in material affording easy construction.

4. The grade on the line is such as to make the grade of the canal below the bed of the river, so that a low open wier will suffice to divert the entire river.

5. Rights of way will not be expensive.

6. The grade adopted was 1.056 feet per mile; levels were taken each 100 feet; alignment and bearings taken with a transit; a number of permanent benches established.

7. The north shore of the lake was traversed and found to be 22,525 feet long from the point of proposed inlet of the diversion canal to the present outlet.

8. The north shore is not impervious to water. If it is used as a reservoir wall, some means of overcoming this weakness will be necessary.

9. The present outlet from the lake to Bear River is not adequate nor suitable to be operated as a canal to return the stored water to the river. Its course is very winding. It can easily be straightened and enlarged. A direct line to the river would be 14.5 miles.

10. A canal line independent of the outlet channel was also examined. Such a channel can be readily constructed in ordinary earthen cut all the way.

11. The lands to be irrigated by the stored waters are mainly along Bear River, in southern Idaho and northern Utah. More than 300,000 acres can be reclaimed from Bear River if the water is supplied.

DUCHESNE RIVER DIVERSION.[a]

Duchesne River is the principal stream of northeastern Utah. It rises on the southern slopes of the Uinta and Wasatch mountains, and flows in a general southeasterly and easterly direction, entering Green River a short distance above the mouth of White River. Its main upper tributary is Strawberry Creek, which drains a high, rolling country, and has a catchment basin of 1,166 square miles. To the east of this is Lake Creek, an important tributary, draining 475 square miles, mainly on the southern slopes of the Uinta Mountains. Its course is in a general southerly direction, and it enters Duchesne River about 3 miles above the Price road bridge. Next to this is Uinta River and its principal tributary, Whiterocks River. These also flow in a general southeasterly direction, and unite in various channels between the Uinta Indian Agency at Whiterocks and the military post at Fort Duchesne. From this point they flow in one channel, forming the main Duchesne River 6 miles below Fort Duchesne and near the Ouray School.

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[a] From report of Cyrus C. Babb.

The greater part of the country drained by Duchesne River and its tributaries has been included in a reservation set aside by Executive order on October 3, 1861, subsequently approved by various acts of Congress, the latest bearing date May 24, 1868. The reservation was supposed to include the entire drainage basin of Duchesne River with its main tributary, Uinta River. The boundary surveys have, however, excluded some portions of the drainage basin, and hence the outline of the reservation does not correspond exactly with the drainage area.

The reservation covers an area of 2,039,040 acres, or 3,186 square miles. Its northern boundary is along the divide of the Uinta Mountains, whose peaks attain elevations of over 13,000 feet. Its western boundary is a portion of the Wasatch Range, while its southern boundary is an irregular line over the rolling country between the basin of Minnemaud Creek and small tributaries of the Duchesne. Immediately south of the southern boundary line is Tavaputs Plateau and Roan Cliffs, which overlook the valley of Price River. Green River forms the boundary line a short distance at the southeastern extremity. The eastern boundary line as originally surveyed was afterwards modified by act of Congress approved May 24, 1888, in order to exclude the so-called "Strip," a triangular area of 7,000 acres east of Fort Duchesne, which contains valuable uintaite, or gilsonite, deposits. Farther to the north a certain portion of the basin of Deep Creek, which enters the Uinta 2 miles above the military post, is not included in the Indian reservation. This latter excluded area contains some fine agricultural land. The greatest due east-west length of the reservation is about 75 miles, with a north-south width of approximately 60 miles.

Throughout a considerable part of its course, Duchesne River flows through valley lands, which, though arid, contain tracts of great fertility when irrigated. Near its headwaters is Strawberry Valley, containing large tracts of nearly level land at an average elevation of 7,500 feet. The altitude is rather high for general agricultural purposes, but the land is adapted to grazing. It is well grassed and will support numerous herds of cattle. The water supply for this valley is excellent, the streams having their source in the Wasatch Mountains, whose canyons sometimes contain snow throughout the year. For a number of seasons this area, to the extent of 675,000 acres, has been leased to certain cattle companies for grazing purposes.

The large extent of excellent farming lands along Duchesne River, taken in connection with the good facilities for grazing in the principal valleys and on the mountain slopes, makes this tract of land one of the most valuable potentially in the future prosperity of Utah. The country is now held for the use of a comparatively few Indians, but the time is not far distant when these must be settled upon definite allotments of land and the remaining lands utilized for the growing needs of a white population. In order to deal justly with the Indians, it is necessary that their allotments be made with reference to the water supply and that a comprehensive system of irrigation be constructed, or at least planned, before these allotments are made. The history of other Indians on arid lands has shown that unless protected with great care the rights to the use of water on Indian lands have

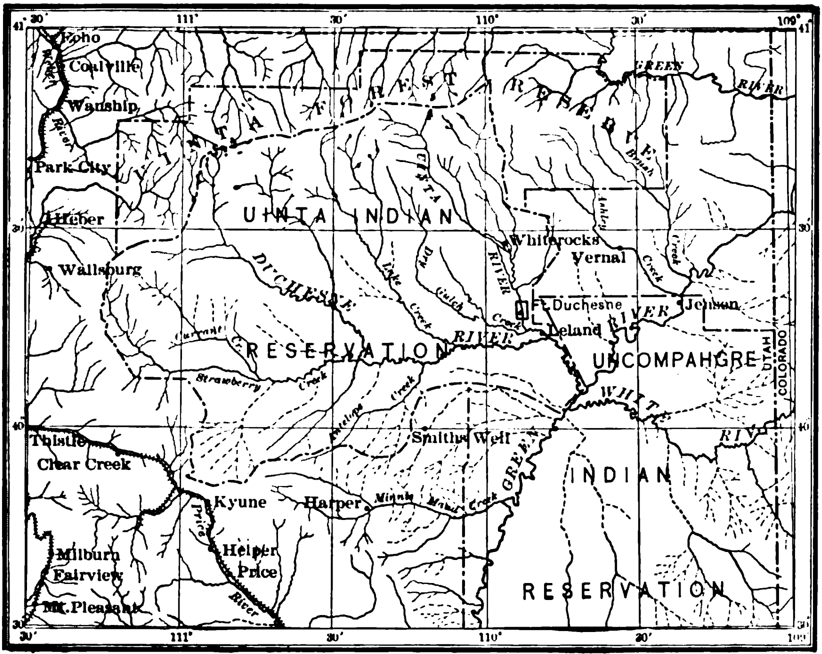

FIG. 60.—Map of Duchesne River Basin.

been gradually lost through neglect or oversight and that the mere allotment of the land without carefully guarding the future use of the necessary water has resulted disastrously to the Indians.

At the present time Duchesne River and its tributaries carry large volumes of water through the year, only a small portion being utilized, the remainder running to waste. Within recent years efforts have been made by various persons and corporations to obtain permission to divert this water from the reservation to adjacent arid lands. Various reports have been received from time to time by the Secretary of the Interior regarding this water supply. Some are to the effect that there is more than a sufficient supply for the future needs of the Indians, and other reports state that if the attempt is made to bring all of the irrigable lands on the reservation under cultivation there will be a shortage of water.

In order to obtain facts concerning the quantity of the water supply, the needs of the Indians, and the opportunies for future developments, an investigation of Duchesne River was begun, the work being carried on by Mr. Cyrus C. Babb. The agricultural lands of the reservation were mapped and systematic measurements made of various streams in order to determine their daily flow. A number of canal lines were also run, in order to estimate the expense of bringing water to the irrigable lands. In all 602 square miles were mapped, on a scale of 1 mile to 2 inches and with a contour interval of 20 feet. Canal lines aggregating 100 miles in length were also surveyed. A number of river stations were established on the main streams, and periodical measurements are still being made.

WATER SUPPLY.

In order to ascertain the amount of water in the various streams the following river stations were established:

One on Whiterocks River, 10 miles above the Indian agency; one on Uinta River, in its canyon, 10 miles above the Indian agency; one at Fort Duchesne, on the main Uinta River; one at the Ouray School, on Uinta River; one on the main Duchesne River, at the bridge on the Price road, about 14 miles from Fort Duchesne; and one on Lake Creek, at the wagon bridge near its mouth. Discharge measurements at these points have been continuous since the establishment of the stations.

The irrigation period in this section extends from the 1st of April to the end of September, or six months. The maximum discharge of the rivers occurs in the early part of this period, gradually decreasing later on through July and August. Estimates on the water supply will be based on the July flow of the rivers when they are comparatively low, but when as much water is needed for irrigation as at any time. The duty of water will be taken at 1 second-foot to 100 acres. This duty is for a minimum year, such as 1900, but will probably not occur oftener than once in five or six years or longer. During ordinary seasons the summer supply will be greater, so that a proportionally lower duty can be used.

Data have recently become available from the Twelfth Census regarding the duty of water in Vernal Valley, a neighboring area that has been rather extensively irrigated. The water supply is from Ashley Creek. The measurements of the census show that 48,355 acre-feet of water was used in 1900 to irrigate 17,471 acres of land. This is an average depth of 2.8 feet. The mean flow throughout the irrigation season was 133 second-feet, or 1 second-foot to 131 acres. It is therefore considered that the assumed duty of 1 second-foot to 100 acres is sufficiently liberal.

The following table gives the water supply in July, 1900 and 1901, for Whiterocks and Uinta rivers at the canyon stations, also for Lake Creek and Duchesne River, together with the amount of land that would be irrigated from each river during that month with a duty of water of 1 second-foot to 100 acres. The gaging station on Duchesne River is below the mouth of Lake Creek, so that it is necessary to deduct the discharge of the latter stream from the records of the former station, as provision is made for the utilization of the Lake Creek waters on the agricultural lands tributary to it.

July water supply.

Stream.	July, 1900.		July, 1901.	
	Discharge.	Area that could be irrigated.	Discharge.	Area that could be irrigated.
	Sec.-ft.	*Acres.*	*Sec.-ft.*	*Acres.*
Whiterocks River	82	8,200	101	10,100
Uinta River	223	22,300	251	25,100
Lake Creek	195	19,500	250	25,000
Duchesne River	182	18,200	347	34,700
Total	682	68,200	949	94,900

From a number of miscellaneous measurements it has been found that there is considerable loss in the rivers of the reservation after they leave their canyons and have continued for a number of miles through the bottom lands. The foregoing table shows that in 1900 and 1901 the July water supply was sufficient for 68,200 acres. As a number of the canal systems described further on have been planned to divert water near the canyons of some of the streams, it is believed that the total water supply of the reservation is sufficient for 80,500 acres during a season of low discharge. In ordinary years the supply will be sufficient for more than 100,000 acres.

UINTA RIVER AGRICULTURAL LANDS.

The section of country that can easily be irrigated from Uinta River, both on and off the reservation, is shown in fig. 60. Within this area there is settled at the present time a large proportion of the Indians of the reservation, and there is to be found the greatest area of land under cultivation lying principally in two tracts, namely, the bench land between Fort Duchesne and the Indian agency at Whiterocks, and the area west of the Ouray school. The principal canals on the reservation are found here and include Canal No. 1, Bench ditch, the small ditches of the Whiteriver Indians, Dry Gulch ditch, and the small ditch from Uinta River 1 mile below the military post. References should be made to preceding annual reports for a description of the agricultural lands of this section.[a]

Regarding the proportion of this land that can be irrigated, it has previously been stated that the July flow of the rivers would be considered the controlling figure. During July, 1900, Uinta River discharged 223 second-feet, which, with a duty of water of 1 second-foot to 100 acres, would have served 22,300 acres. For the same month Whiterocks River, with a discharge of 82 second-feet, would have served 8,200 acres.

The best method for the irrigation of the Uinta area is by the enlargement of the present canal system. Increasing the carrying capacity of Canal No. 1 would enable it to supply sufficient water to the mesa west of Uinta River. It should also be extended, commencing at about the fourth milepost and being carried westward around the head of the gulch down which it is now turned. This extension would supply water for the entire mesa, 1,930 acres, extending immediately west of the Government farm valley. Bench ditch could also be enlarged. If Whiterocks River is to be diverted from the reservation, the Deep Creek country could also be supplied from Uinta River.

There is an area covering 6,600 acres just east of the reservation, in what is known as the Strip, which it is possible to irrigate. East of the Ouray School is a large tract of agricultural land bounded on the west by the reservation boundary line and on the east by Green River. It is in the form of a rude triangle, and comprises approximately 21,200 acres. The chief features for a canal to irrigate this land would be as follows: It should head on Uinta River at such an elevation as to cross the little divide in sec. 35, T. 1 S., R. 1 E. It will therefore be considered as heading at the 5,180-foot contour. Within a mile and a half it would cross Deep Creek, continue eastward a short distance, and then turn southward. It would control most of the Strip country, and could be brought across the Vernal divide at the 5,100-foot contour, at a distance of 11 miles from its head. The fall would be greater in its 3-mile course down the dry wash. The water could be diverted again at about the 4,900-foot contour. Thence the general direction of the main canal would be southeasterly for 8 miles, then practically due south, in which direction it would continue until

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[a] Twenty-first Ann. Rept., Part IV, pp. 305-330; Twenty-second Ann. Rept., Part IV, pp. 366-388; House Doc. No. 671, 57th Cong., 1st sess.

Green River and the lower end of the triangular tract are reached. The following are the approximate distances along this canal from its head:

Distances from point to point of canal to irrigate lands off the reservation.

	Miles.
Deep Creek	1.5
Reservation line	4
Vernal divide	11
4,900-foot contour in wash	14.5
At bend to the south	22
End of canal	29

It will thus be seen that a canal heading at about the 5,180-foot contour would furnish water for most of the agricultural land of the Strip, cross the divide near the lower extremity of the gilsonite claim, and irrigate lands to the south. There would be no difficult engineering features along the route. The excavations for the greater portion of the way would be in the cemented gravel common to the region. This formation is difficult, and hence expensive, to work, and the cost would be near that of rock cutting, or about $1 per cubic yard.

The amount of arable land, both on and off the reservation, tributary to Uinta and Whiterocks rivers is as follows:

Lands irrigable from Uinta and Whiterocks rivers.

	Acres.	
On reservation:		
River bottom	8,900	
Mesa west of Uinta River	21,400	
Bench country	7,100	
Miscellaneous areas north of military post	9,600	
Deep Creek Basin	16,300	
		63,300
Off reservation:		
The Strip	6,600	
Green River area	21,200	
		27,800
Total		91,100

LAKE CREEK AGRICULTURAL LANDS.

Lake Creek is an important tributary of Duchesne River, draining a section of country immediately adjoining the Uinta Basin on the west. It discharges into Duchesne River about 3 miles above the bridge on the stage road to Price. There has been more or less discussion regarding the feasibility of the diversion of the waters of the creek to irrigate lands adjoining Uinta River, especially those under Canal No. 1, and it was thought desirable to investigate the possibilities of this stream for irrigation.

The Lake Creek agricultural area can naturally be divided into four portions. The first comprises a strip of 18,000 acres of bench land, extending from the junction of the two forks southward about 14 miles, when it broadens out to the second division, the strip draining into Dry Gulch Creek, consisting of 12,600 acres. The third area is the mesa between the latter and Duchesne River, and contains 5,300 acres. The fourth section, comprising an area of 16,100 acres, is west of the lower course of Lake Creek in an approximately triangular strip immediately north of Duchesne River.

The average flow of this stream in July, 1900, was 195 second-feet, or sufficient for 19,500 acres. Measurements made during the next month, at the junction of the two main forks, about 25 miles above the mouth, showed a considerable loss after the river leaves its canyon. In August this loss exceeded 50 per cent, the average flow at the forks being about 200 second-feet and the discharge at the mouth only 97 second-feet. If the loss during July were proportional there would have been at the forks sufficient water for 39,000 acres. It is believed to be safe to assume that there will be sufficient water in Lake Creek at the forks to irrigate 30,000 acres during dry seasons.

If water for 10,000 acres be set aside in the fourth section described, or that west of Lake Creek, the quantity required, at the usual duty, will be 100 second-feet. There will then remain water for 20,000 acres of the land east of the creek, or a discharge of 200 second-feet.

Lake Creek flows in a gorge about 200 feet deep, and the most feasible point for its diversion to the east side is about one-fourth of a mile below the junction of the North and South forks. Here the cliffs on the east side are in a succession of terraces, and a canal taken out at this point could in a distance of 1½ miles bring water to the top of the mesa.

A map was made, on a scale of 200 feet to the inch and with a contour interval of 5 feet, of the region extending from the junction of the two forks 2½ miles downstream, including the tops of the highest terraces. The map shows sufficient detail for the location of the canal line, and is on a sufficiently large scale to permit computation of the amount of excavation, from which an estimate of the cost of this portion of the canal can be made.

A canal on a grade of 0.0005, or 2.64 feet to the mile, with a bottom width of 12 feet, side slopes of 1 to 1, and a depth of 4 feet, will have a cross-sectional area of 64 square feet. Assuming the coefficient of roughness, or value of *n* in Kutter's formula, to be 0.020, this would give a discharge of 200 second-feet. The length of the canal from the head gate to the top of the mesa is 1½ miles. In the construction of this portion it will be necessary to move 27,040 cubic yards of earth, which will cost, at 25 cents per cubic yard, $6,760. After the canal has reached the top of the upper terrace, construction would be in a flat country and the cost per mile would approximate $1,500. The mesa has a very steep slope, but has a subsoil of the same formation as that along canal No. 1—partially cemented gravel. It is believed that a canal can be built directly down the mesa and that the amount of erosion will be very small.

After the main canal, heading below the forks of the creek, has attained the top of the mesa it could be divided, one branch extending southward, to serve the lands of the upper section, and the other branch to continue in a general easterly direction for about 4 miles, when it could be turned into the gulch (shown on the map) in sec. 6, T. 1 S., R. 3 W. This wash has its outlet in sec. 21, T. 2 S., R. 3 W., and the water could here be diverted and used to irrigate the second division, known as the Dry Gulch country.

It is not considered feasible to irrigate the third section, the mesa north of Duchesne River, owing to the insufficiency of the water supply and the excessive cost of the necessary canal. Water could be taken to it by carrying a lateral from the mouth of the gulch mentioned, southeasterly across the flat country for about 4 miles, when a sidehill would be encountered, along which the canal would run for a distance of about 3 miles before the top of the mesa could be reached.

Lake Creek continues in its gorge from the junction of the two forks down to a point about 13 miles below where occurs the narrowest point, in sec. 20, T. 2 S., R. 3 W. Beyond here the valley broadens rapidly to the agricultural area on the west side of the creek. The width at the narrowing of the gorge is about 800 feet, with vertical cliffs on either side approximating 200 feet in height. This site has been mentioned as a possible location for a dam and the creation of a reservoir. The project, however, is not feasible, as the gorge does not broaden sufficiently above the narrows and as the fall of the creek is about 80 feet to the mile. A dam 160 feet high would in this case back the water only 2 miles up the river.

The fourth section of agricultural land tributary to Lake Creek, comprising 16,100 acres on the west side of the creek and north of Duchesne River, is in T. 3 S., R. 3 W. Of the better quality of land there are 10,000 acres. As previously stated, this area will require 100 second-feet. A canal to carry this amount, built on a grade of 3.7 feet to the mile, bottom width 8 feet, side slopes 1 to 1, and depth 3 feet, would have a cross-sectional area of 33 square feet. Assuming the coefficient of roughness or value of *n* in Kutter's formula to be 0.020, would give the necessary discharge, 100 second-feet.

This canal should head 2½ miles below the narrows, in sec. 3, T. 3 S., R. 3 W., and should continue in a general southerly direction, covering all of the agricultural land of this section. At no place would the cost of excavation be excessive, as the canal would pass through the formation common to this section (a more or less cemented gravel) and as the topography is relatively flat.

If a canal were diverted from about the forks of Lake Creek and carried westward to the Uinta country, it would have to pass through a very rough section, besides crossing two deep gulches, one of them being Dry Gulch, and the cost of its construction would be excessive. On account of the latter, and also owing to the extent of agricultural land immediately tributary to Lake Creek, for which there is not a sufficient water supply, it is not considered best that any attempt be made to carry a canal from this stream to the Uinta area.

The following table gives the areas of the four sections of arable lands tributary to Lake Creek:

Lands irrigable from Lake Creek.

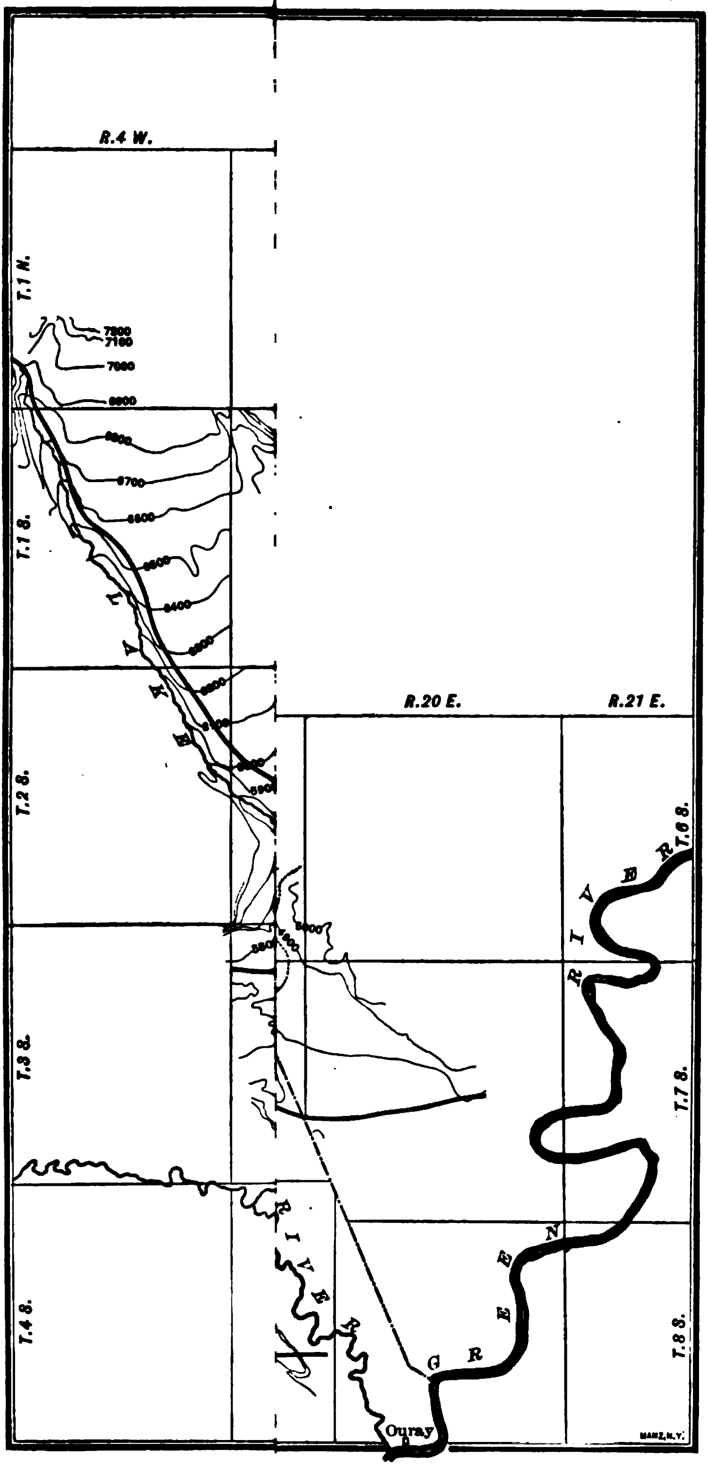
	Acres.
North section	18,000
Dry Gulch Basin	12,600
Mesa north of Duchesne River	5,300
West of creek	16,100
Total	52,000

DUCHESNE RIVER AGRICULTURAL LANDS.

Duchesne River from its junction with Strawberry Creek has a general easterly course, flowing through bottom lands averaging 1¼ miles in width. Immediately southward occurs a line of bluffs about 200 feet in elevation, from the top of which extends southward a series of mesas. This higher land west of Antelope Canyon is dissected by numerous side canyons draining toward Duchesne River, and is not suitable for agricultural purposes. East of Antelope Canyon, however, the mesas are but little cut up, and as a result there is a large tract of land eminently suited to irrigation if water could be brought to it.

The area of agricultural lands is naturally divided into two sections. The first section extends eastward from Antelope Canyon to approximately Smith's well road, and has an area of 21,800 acres, 8,000 acres of which are bench country, the remaining 13,800 acres being included within the Sixmile draw, a designation arising from the fact that the drainage line of the draw is 6 miles south of the Duchesne Bridge along the Price stage road. Continuing eastward, a rough, broken country, from 5 to 7 miles wide and of about 22 square miles area, separates the first division of Duchesne agricultural lands from the second division. The latter is the bench in the southeast corner of the reservation immediately west of Lower Duchesne River after it has made the bend from its general easterly course to its southeasterly course, and comprises 21,900 acres.

The third area susceptible of irrigation and for which water should be supplied is the bottom land of Duchesne River from the mouth of Antelope Canyon downstream, comprising 14,300 acres. Of this area the section from the mouth of Lake Creek eastward, comprising 6,800 acres, has already been allotted to the Uncompahgre Indians. The


R.4 W.
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R.21 E.
T.6 S.
T.7 S.
T.8 S.
R I V E R
G R E E N
R I V E R
Ouray
MANZ, N.Y.

remainder westward to Antelope Canyon, comprising 7,500 acres, is available for future allotment. Some Uinta Indians are at present irrigating lands in the latter section, receiving their water from the ditch heading 1½ miles above Antelope Canyon.

The fourth section of agricultural land which should receive water from Duchesne River is that west of the Ouray School, between Uinta and Duchesne rivers. A portion of it is occupied by Indian farms, and is irrigated from a ditch heading on the left bank of Duchesne River about 8 miles above the school. It comprises an area of 5,200 acres.

The following table gives the amount of agricultural lands tributary to Duchesne River:

Lands irrigable from Duchesne River.

	Acres.
Upper section:	
Mesa	8,000
Sixmile draw	13,800
Lower bench:	
Irrigable under 4,968-foot contour	7,000
Nonirrigable	14,900
Bottom lands:	
Upper	7,500
Lower	6,800
Ouray School section	5,200
Total	63,200

DUCHESNE RIVER CANAL LINES.

During 1900 surveys of a number of canal lines were run for the upper Duchesne area, the work being in charge of Mr. A. L. Fellows. The topographic work shows that an elevation of 5,600 feet should be attained on the mesa in order to reclaim the greater portion of it. On Duchesne River there is an elevation somewhat greater than this, about 6 miles above the mouth of Strawberry Creek, and from there a line for a canal was started, with the idea of taking water from the right bank. The line was run a distance of 20 miles, then across Strawberry Creek to the south side, and from that point eastward another 20 miles before the agricultural area was reached. On account of its length, and also because of the excessive cost of construction, the line was considered impracticable and was abandoned. A second line was then started, the initial point being a short distance below the mouth of Strawberry Creek, on the right bank of Duchesne River. The canal would follow the river closely for a distance of 8 miles, or to a point about 3 miles west of the Indian village near the mouth of Antelope Canyon. About opposite this settlement the line has receded to perhaps 1½ miles from the river. It soon reaches Antelope Canyon, up which the line may run for a distance of about 2 miles, thence crossing and turning down again, keeping in front of the hills, with the exception of a few cut-offs, until the top of the mesa is reached, at an elevation of 5,340 feet. This point is about 6 miles southeast from the Duchesne bridge and 4 or 5 miles east of Antelope Canyon. This line would cost $300,000, and 21,800 acres would be reclaimed.

Upon the completion of the survey of the lower Duchesne benches in 1901 attention was given to the location of a canal to the same. The topographic map disclosed a low divide of about 5,000 feet elevation in sec. 11, T. 4 S., R 1 W., and therefore shows that a canal controlled by this divide and allowing for sufficient grade should head 1¼ miles above Duchesne bridge, at an elevation of 5,021 feet. When it has attained the lower mesa it is at an elevation of 4,968 feet, and therefore only the land under this contour, or 7,000 acres, can be irrigated. With a duty of water of 1 second-foot to 100 acres a canal having a capacity of 70 second-feet will be required. With a grade of four-hundredths of 1 per cent, or a fall of 2.11 feet per mile, a bottom width of 8 feet, a depth of 3 feet, and side slopes of 1 to 1, the area will be 33 square feet. Assuming a coefficient of roughness of about 0.020 will give the necessary discharge of 70 second-feet.

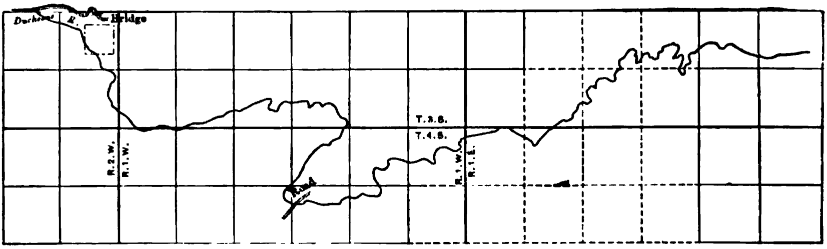

FIG. 61.—Duchesne River lower canal line.

The initial point of the survey was on the right bank of Duchesne River, in sec. 23, T. 3 S., R. 2 W. (fig. 61). The line extends in a general southeasterly direction across the Duchesne bottom land for a distance of 3.4 miles, when it encounters a steep sidehill, along which it continues for 3.8 miles. At this point, in sec. 34, T. 3 S., R. 1 W., a tunnel 1,400 feet in length is planned to pierce the ridge. The line then takes a general southwesterly direction for 2.7 miles through a comparatively flat country, when it crosses what is known as the Smith's well road, in sec. 10, T. 4 S., R. 1 W., 9.7 miles from the head. Beyond the road the canal soon strikes a rough, rocky country, in which construction work will be expensive, requiring a number of lengths of flumes. The canal finally appears on the mesa at about station 1,100, or 21 miles from the head. The line ended at station 1,245. The elevation at this point is 4,968 feet, so that only the land under this contour, or about 7,000 acres, can be irrigated. The approximate cost of building the 23.6 miles of canal to the head of the irrigable land will be $105,000.

In considering the amount of water available for irrigation from Duchesne River, it is necessary to deduct the discharge of Lake Creek from the discharge of Duchesne River at the Price bridge, as plans for the utilization of the flow of the former stream have already been made. In July, 1900, Duchesne River was discharging 377 second-feet. Deducting 195 second-feet (the flow of Lake Creek) leaves a discharge of 182 second-feet for Duchesne River, or sufficient water for 18,200 acres.

On September 15 and October 5, 1900, measurements were made on Duchesne River immediately above the mouth of Strawberry Creek, and also of the latter stream. The combined discharge, representing the flow of Duchesne River below the mouth of Strawberry Creek, was 300 and 324 second-feet on the respective dates. At the main gaging station on Duchesne River the discharge on the same dates was 275 and 315 second-feet, respectively. Deducting from the two latter figures the discharge of Lake Creek, will leave 155 and 185 second-feet, respectively. Therefore, on September 15, 1900, Duchesne River immediately below the mouth of Strawberry Creek was carrying 300 second-feet, while 23 miles below, at the main gaging station, there was a discharge of only 155 second-feet. Similarly, on October 5, the discharge above was 324 second-feet and below 185 second-feet. The loss is seen to be in the neighborhood of 50 per cent. This is a phenomenon similar to that noted on Uinta River and Lake Creek, i. e., a loss of about 50 per cent after each stream has flowed for some distance through bottom lands.

It has been shown that in July, 1900, there was sufficient water in Duchesne River to irrigate 18,200 acres. As some of the canals have been planned to take water from the upper stretches of the river, it is believed that the water supply is sufficient for 20,000 acres, exclusive of Lake Creek.

The table on page 300 shows that 63,200 acres of irrigable land are tributary to Duchesne River. As the water supply in 1900 was sufficient for only 20,000 acres, it becomes necessary to make a selection of the lands to be irrigated.

To serve 21,800 acres of the upper section the canal should head immediately below the mouth of Strawberry Creek, and would be 36 miles long before the irrigable lands could be reached. The cost would be $300,000, according to the report of Mr. A. L. Fellows. This would make the cost of reclamation $13.70 per acre. The entire water supply of Duchesne River is sufficient for only 20,000 acres, and the cost, if the water should be applied to this upper section, would be $15 per acre, not including the distributary canal system.

In the second section of the lower bench only a portion of the 21,900 acres are irrigable. It was shown in the description of the lower Duchesne canal line that, owing to a controlling divide, the canal must be taken from the river at an elevation of 5,021 feet. When it has attained the lower mesa it is at an elevation of 4,968 feet, and therefore only the land under this contour, or 7,000 acres, can be irrigated. The cost of construction of this canal will approximate $105,000, or $15 per acre irrigated. The remaining 14,900 acres on this bench might be irrigated by a pumping plant, but the expense would be considerable.

The bottom land of the river, both above and below Lake Creek, comprising an area of 14,300 acres, can be reclaimed, also the 5,200 acres in the vicinity of the Ouray School. The canals for these areas will be in the flat, sandy country of the bottom lands, and will be relatively cheap to build, with no difficult engineering problems. The fall of the country is greater, however, than a canal can have without erosion, so that occasional drops will have to be provided.

SUMMARY OF LAND CLASSIFICATION AND WATER SUPPLY OF RESERVATION.

The following table shows the amount of agricultural land of the reservation which is tributary to the various streams and which should naturally be irrigated from them:

Arable lands.

	Acres.	
Uinta River area:		
On reservation—		
River bottom	8,900	
Mesa west of Uinta River	21,400	
Bench country	7,100	
North of military post	9,600	
Deep Creek Basin	16,300	
		63,300
Off reservation—		
Strip	6,600	
Green River area	21,200	
		27,800
Lake Creek area:		
North section	18,000	
Dry Gulch Basin	12,600	
Mesa north of Duchesne River	5,300	
West of creek	16,100	
		52,000
Duchesne River area:		
Upper section—		
Mesa	8,000	
Sixmile Draw	13,800	
Lower bench—		
Nonirrigable	14,900	
Irrigable, under 4,968-foot contour	7,000	
Bottom lands—		
Upper	7,500	
Lower	6,800	
Ouray School section	5,200	
		63,200
Total arable land tributary to the three rivers		206,300

In July, 1900, there was sufficient water from the four rivers to irrigate 68,200 acres. (See table on p. 291.) Lake Creek furnished water for 19,500 acres. It has been shown, however, that there is considerable loss in the channel of this stream, and it is believed that there is sufficient water for 30,000 acres, or 10,500 acres more than the foregoing table shows. Similarly for Duchesne River, it is believed that there will be water for 20,000 acres during a dry season, or sufficient for 1,800 acres more than the table shows. This will make the total supply from the four rivers sufficient for 80,500 acres. During ordinary seasons the supply will be sufficient for 115,000 acres.

It is somewhat difficult to determine the quantity of land that the Uinta and Whiterocks Indians will require, if some time in the future land be allotted to them in severalty and the remainder of the reservation be thrown open to settlement. Estimates can be made, however, based upon the statistics of the allotment on the Uncompahgre Reservation, authorized by act of Congress of June 9, 1897. There were 45,440 acres allotted to 550 Indians, or about 80 acres to each person. Half of this was on irrigable lands, the remainder on lands for grazing purposes. This, then, gives 40 acres of irrigable land to each man, woman, and child on the reservation. This quantity will be used in the following discussion, as it conforms to the practice in the allotment of Indian lands. One-eighth of that amount, or 5 acres, would be more equitable.

The last census shows a total pupulation of 830 Uinta and Whiterocks Indians. On the above basis of 40 acres to the individual, 33,200 acres of irrigable lands will ultimately be required by these Indians. The 550 Uncompahgres who have already been allotted lands require 22,000 acres, making a total of 55,200 acres of irrigable lands.

As the water supply is sufficient for 80,500 acres, there will be a surplus for 25,300 acres above the requirements of the Indians. From all reports the 1900 flow of the streams was unusually low, and the average summer discharge will be greater than the figures of that year.

If the area which could be irrigated from Whiterocks River, 8,200 acres, be deducted from the 80,500 acres, there will remain 72,300 acres, giving a surplus of 17,100 acres above the future needs of the Indians.

Several ways are open for the future settlement of these Indians on irrigable lands. The results of the investigations show that there is a greater tract of agricultural land having a sufficient water supply than the future needs of the Indians will require. The Department has its choice of location, and it also has its choice of whether the Indians shall be settled on large tracts or on detached areas, the whites being permitted to take up intermediate sections, so that Indians and whites would be intermingled. Both policies have been advocated in the discussion of the Indian question, but it would seem that the former method, that of having the Indians occupy large tracts of land by themselves, is preferable.

If the Department should pursue the policy that water shall be used only on lands tributary to the rivers, and if the irrigable areas off the reservation should be included within the reservation, it would follow, on account of the location of the latter, that they should receive some of the Uinta or Whiterocks water, as they are naturally tributary to it. In fact, this area off the reservation is much better for agricultural purposes than some of the Uinta area within the reservation. If water is permitted to be diverted from Whiterocks River or Uinta River to irrigate these lands off the reservation, or if the surplus agricultural lands beyond the needs of the Indians are placed upon the market, the rights of the Indians should be protected as fully as possible.

It was recommended in the first progress reports[a] that if a ditch were to take water from Uinta River off the reservation it should be located rather well downstream; and it was there recommended that no diversion be allowed north of secs. 26 and 27, T. 1 S., R. 1 E. A canal taken out within these limitations could control all of the arable area off the reservation. Further consideration of this matter, however, leads to the belief that if the Indian canals should head above other diversions complications might still arise, and it is believed that if the flow of some streams could be entirely disposed of, i. e., sold outright for the benefit of the Indians, it would be much better for them than to have a joint control with the white settlers. Whiterocks River is such a stream, and we have already seen that exclusive of its discharge there will still be sufficient water on the reservation for 72,300 acres, or for 17,100 acres more than the Indians will eventually require.

It therefore seems that the exclusive right to Whiterocks water might be disposed of, and that it would be right and just for the Department so to do. There is only a small area of suitable land on the reservation that is naturally tributary to this stream (the 7,000 acres in the Deep Creek country), and even that section could, if desired, be served from Uinta River.

If the Department is of the opinion that the Indians are entitled to only the water which they can economically use, this Whiterocks water could be practically given away. If it is held, however, that the Indians own the water on their reservation, a value could be placed upon it and it could be offered for sale.

The question next arises, What is the value of an irrigation stream? A fair estimate of the value of agricultural lands is considered to be $25 an acre. With a duty of water of 1 second-foot to 100 acres, this would mean that 1 second-foot of water is worth $2,500. The value of the stream depends upon its low-water discharge. In the case of Whiterocks River the records show that the minimum July discharge is 82 second-feet. This amount of water, at the rate of $2,500 a second-foot, is worth $205,000. From this amount there should be deducted the cost of the canal system to bring the water to the land.

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[a] Twenty-first Ann. Rept., Part IV, p. 328.

WASHINGTON.

The western side of the State of Washington, bordering the Pacific Ocean, is humid. In fact, the rainfall is probably as heavy as in any other part of the United States. The forests are consequently dense and extremely valuable, and the disposal of these has resulted in turning into the reclamation fund an amount so large that Washington stands well up in the list of States from which great revenues are being derived.

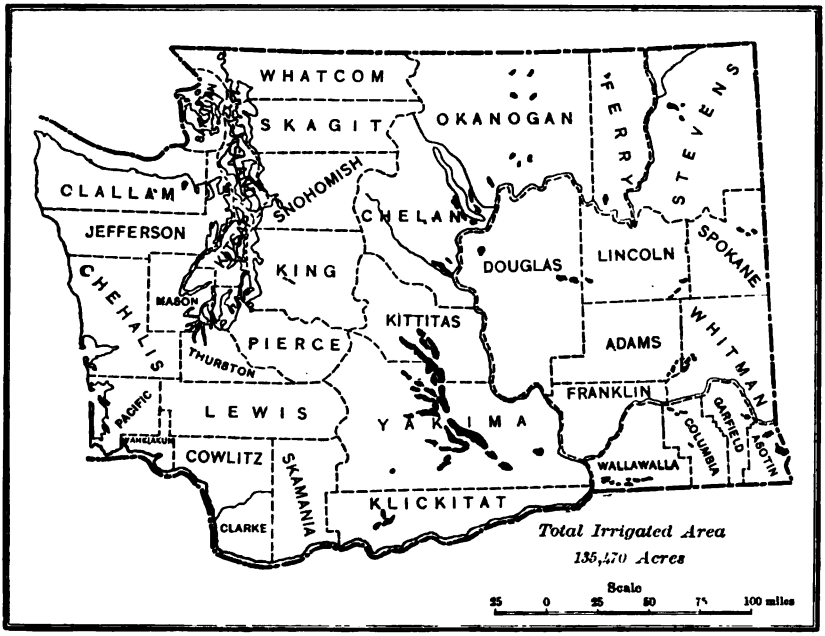

Fig. 62.—Map of irrigated areas in Washington.

In the center and eastern part of the State the climate is arid, and here, on the vast Columbia Plains, are great areas of vacant public land, aggregating nearly 12,000,000 acres. Columbia River, flowing around and partly through this body of vacant land, carries a large amount of water, but the stream is so far beneath the general level of the country that the use of its waters is almost impossible.

The broad land grant of the Northern Pacific Railroad crosses the State and takes in every alternate section, so that the Government lands form a checkered pattern. Reclamation on a large scale is thus complicated by the existence of alternate sections of land in private ownership.

Irrigation has been most fully developed in Yakima Valley, immediately east of the Cascade Range. The large streams coming from the mountains have rendered possible a relatively cheap and easy diversion of the water. There are also in the mountains a number of lakes and valleys where water can be stored at small expense. The lands in Yakima Valley are included within the Northern Pacific grant, and the Government sections have been largely taken up, so that while there remains a considerable amount of unutilized land, the title to it has for the most part passed into the hands of settlers or corporations.

The total area irrigated in the State in 1899 was 135,470 acres; ten years earlier it was only 48,799 acres. Most of this land is in Kittitas County near the head of Yakima River and in Yakima County along the middle portions of the river.

The most feasible opportunities for reclamation are those offered by Yakima River and its tributaries, the principal obstacle being the fact that much of the land to be benefited is in private ownership. Already steps have been taken to utilize some of the storage reservoirs in the Cascade Mountains, and it is not desirable for the Government to forestall work which can be carried on by private parties. The river measurements carried on through several years throw light upon the possibilities of storage, but a thorough investigation of the entire river is necessary before it can be determined what projects will be of the greatest public importance. Such an examination is greatly facilitated by the existence of good topographic maps covering much of the drainage area, so that in this respect Yakima River is more favorably situated than some of the other streams.

The matter of chief interest in the center of the State is the possibility of obtaining deep or artesian waters over the dry Columbia Plains. Before determining this a very thorough study of the geologic structure must be made. Preliminary work in this direction has been done by Prof. Israel C. Russell, of Ann Arbor; also by Mr. George Otis Smith, and in 1902 by Mr. Frank C. Calkins, assistant geologist.

There are numerous valleys throughout the State where arid or semiarid lands can be reclaimed in the future, but each of these requires special attention, and there has been little demand for development, the most pressing needs being evidently in the unwatered portion of Yakima Valley. The table below shows the vacant public land on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in Washington on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total area.
	Acres.	*Acres.*	*Acres.*	*Acres.*
Adams		259,396	826,042	1,085,440
Asotin	214,807	13,180	175,853	403,840
Chehalis	31,660	387,570	840,290	1,259,520
Chelan	925,532	736,440	302,828	1,964,800
Clallam	95,309	525,792	535,379	1,156,480
Clarke	41,127	636	371,677	413,440
Columbia	177,131	117,200	266,309	560,640
Cowlitz	110,071		622,729	732,800
Douglas	1,619,684		1,431,836	3,051,520
Ferry	720,768	729,431	30,121	1,480,320
Franklin	235,021	426,540	139,079	800,640
Garfield	118,584	75,474	269,942	464,000
Island		2,193	150,127	152,320
Jefferson	53,258	819,529	256,813	1,129,600
King	468,338	7,750	836,552	1,312,640
Kitsap	12,202	8,214	240,064	260,480
Kittitas	772,698	58,373	713,889	1,544,960
Klickitat	425,388	240,441	664,731	1,330,560
Lewis	194,536	396,020	904,484	1,495,040
Lincoln	116,187	700	1,354,473	1,471,360
Mason	29,160	168,405	437,955	635,520
Okanogan	2,126,000	1,146,289	131,231	3,403,520
Pacific	125,655	935	465,410	592,000
Pierce		312,933	681,627	994,560
San Juan	19,380	2,955	97,345	119,680
Skagit	365,186	348,476	485,698	1,199,360
Skamania	296,645	640,405	178,470	1,115,520
Snohomish	67,123	381,935	607,582	1,056,640
Spokane	86,120		1,051,160	1,137,280
Stevens	1,671,119		853,681	2,524,800
Thurston	30,816	1,360	456,144	488,320
Wahkiakum	2,301	640	171,779	174,720
Wallawalla	54,695	303,530	459,055	817,280
Whatcom	92,083	905,480	427,077	1,424,640
Whitman	4,117	255,182	1,087,901	1,347,200
Yakima	665,955	1,469,390	1,566,415	3,701,760
Total	11,968,656	10,742,796	20,091,748	42,803,200

WYOMING.

In Wyoming the opportunities for construction of storage reservoirs are notably good and there are vast areas of vacant public land which may be reclaimed. The funds to the credit of this State are, however, not notably large, illustrating the condition noted before that the States having the least funds offer the most feasible projects. The Union Pacific land grant crosses the southern border of the State, and much of the arid land there is in the possession of the railroad or has been disposed of to cattle and sheep men. The northern part of the State is largely Government land, there being in round numbers 47,000,000 acres of unappropriated and unsurveyed land in Wyoming, this being over two-thirds of the entire land surface of the State.

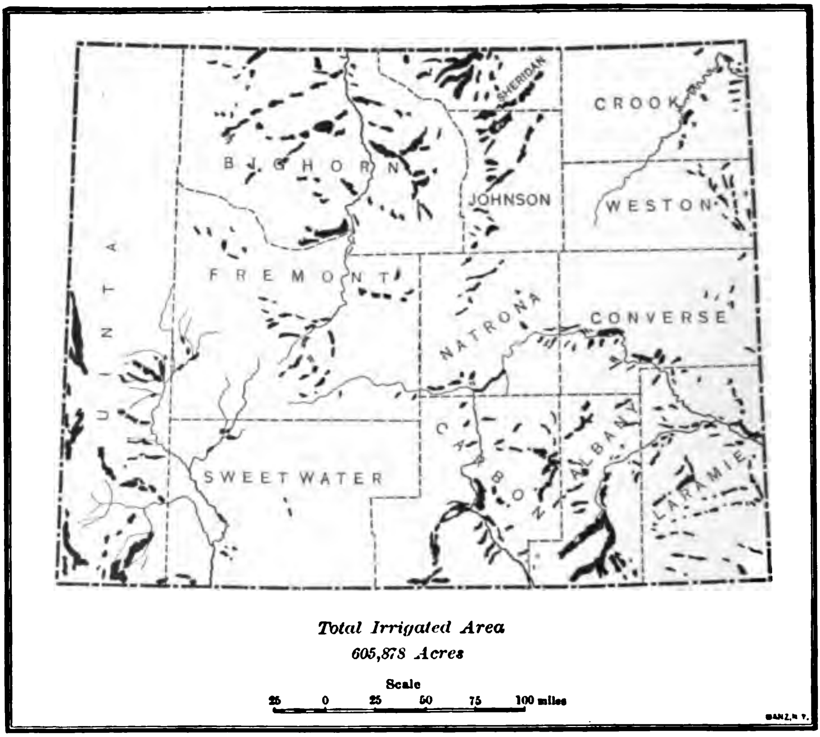

FIG. 63.—Map of irrigated areas in Wyoming.

The area irrigated in 1899 was 605,878 acres, the greater part of this being in pasture, hay, and forage, the altitude of the State rendering the production of orchards, small fruits, and vegetables relatively small. The table below shows the vacant public land on June 30, 1901. A summary of the conditions, by States, on June 30, 1902, taken from the report of the Commissioner of the General Land Office, will be found on page 19.

Unappropriated, reserved, and appropriated lands in Wyoming on June 30, 1901.

County.	Unappropriated and unreserved.	Reserved.	Appropriated.	Total areas.
Albany	1,633,296	264,476	854,228	2,752,000
Bighorn	6,297,461	989,464	531,315	7,818,240
Carbon	3,601,474	997,435	532,611	5,131,520
Converse	3,924,657	....	400,463	4,325,120
Crook	2,917,482	57,923	502,995	3,478,400
Fremont	5,493,722	2,342,998	261,200	8,097,920
Johnson	2,337,144	....	330,376	2,667,520
Laramie	2,912,891	....	1,558,149	4,471,040
Natrona	3,242,933	....	205,387	3,448,320
Sheridan	1,184,902	5,733	453,525	1,644,160
Sweetwater	6,348,424	297,586	80,390	672,400
Uinta	5,233,536	3,039,403	674,261	8,947,200
Weston	2,543,694	....	396,466	2,940,160
Total	47,671,616	7,995,018	6,781,366	62,448,000

The State as a whole is higher on the south than it is on the north, and therefore there is a more genial climate in the valleys adjacent to Montana than farther south. This is particularly the case in the vicinity of Buffalo and Sheridan, on the east of the Bighorn Mountains, and in the Bighorn Basin to the west. Irrigation development, being favored by a relatively large and well-distributed water supply, has proceeded rapidly and there is already demand on the small streams for storage.

Work under the reclamation law has been begun at two points in the State—on the streams going easterly from Bighorn Mountains and on Sweetwater River in the central part of the State above its junction with North Platte River. Both of these localities have been described in a report by Capt. Hiram M. Chittenden, published as House Document No. 141 of the Fifty-fifth Congress, second session. The work east of the Bighorn has been in charge of Mr. Jeremiah Ahern. It consists mainly of the surveying of Lake De Smet, in order to ascertain the cost and feasibility of using it as a reservoir, the water supply to be obtained from the spring floods of Piney and adjacent creeks. In this connection other possible reservoir sites in the mountains were inspected, and comparisons were drawn between the practicability of various alternate projects.

The lands along Piney Creek are nearly all in private possession, and irrigators, being short of water in the summer, have already begun construction of several reservoirs in the mountains. It is not desired to interfere with private enterprise in this direction, and, on the other hand, if the Government reservoir is to be built, there should be no question as to available waters to fill it. In other words, it is necessary to ascertain that when these are complete there will still be a surplus to fill Lake De Smet.

The lands to be irrigated below Lake De Smet are partly in private ownership, being in long, narrow strips, fringing all of the streams. Above this belt of bottom land are areas of good quality to which water can be brought. The surveys made during 1902 show that the project as a whole is probably feasible and that there are several alternatives to be considered. The total cost has not yet been ascertained, and there are a number of details to be completed before plans and specifications can be submitted.

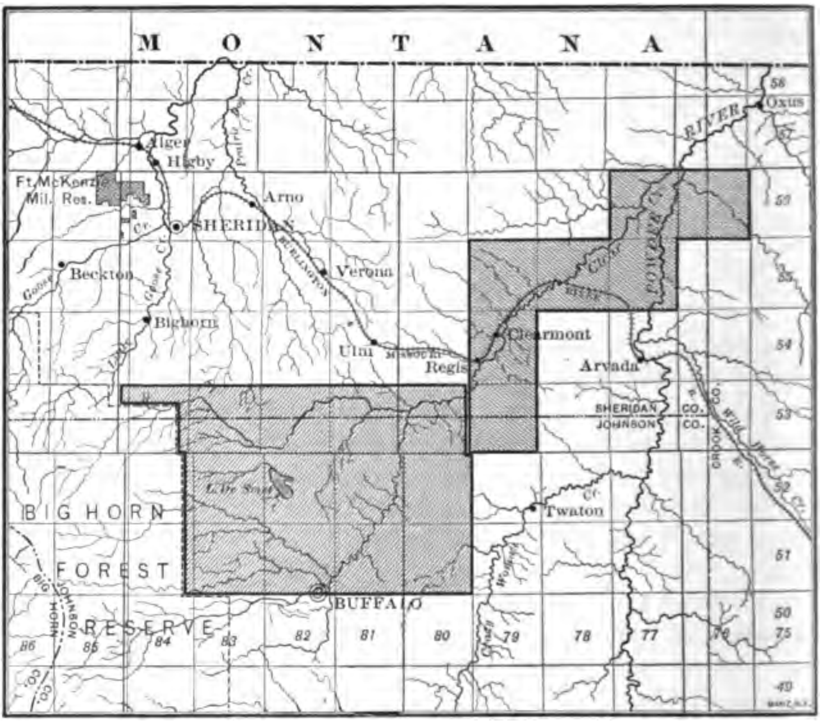

Fig. 64.—Map of lands temporarily withdrawn near Lake De Smet, Wyoming. (Additional lands have been reserved since this map was drawn.)

SWEETWATER PROJECT.

Sweetwater River receives the drainage of the central part of Wyoming and flows easterly. A short distance before it joins North Platte River it cuts through granite ridges, one of which, in particular, is notable for the narrow canyon through which the river passes. This is known as "Devils Gate." At first sight it appears as though the granite ridge were shattered, or faulted, and that it would be difficult to prepare suitable foundations for a dam in the gap. It is evident, however, from the result of diamond-drill borings, that the river has cut a channel through the granite and flows over solid bed rock, a condition which has rarely been found in similar situations.

The locality, as above noted, was examined by Capt. Hiram M. Chittenden and favorably reported upon. There is evidently ample reservoir capacity, and the chief questions to be determined are the supply available to fill the reservoir and the cost of the dam. Measurements of the river were taken at the gap and a diamond-drill party was instructed to begin operations, the work being under the immediate direction of W. W. Schlecht. He reports that considerable delay was experienced in getting the machinery on the ground, but that before cold weather came on, freezing the pump and preventing the operation of drilling, the party had succeeded in sinking four holes into bed rock. These reached granite at depths below the sand of from 14 to 15 feet and penetrated the granite for about 20 feet, finding solid rock. A contour map of the reservoir was also made, and material obtained for preparing estimates of the cost and capacity of the reservoir.

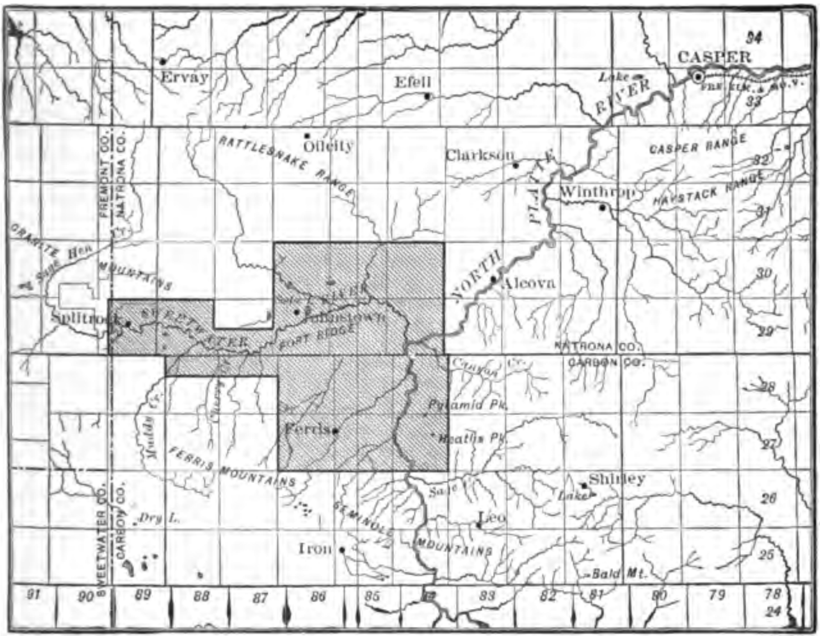

FIG. 65.—Map of lands temporarily withdrawn on Sweetwater River, Wyoming. (Additional lands have been reserved since this map was drawn.)

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LANDS IN SOUTHERN CALIFOR

: vacant public lands.

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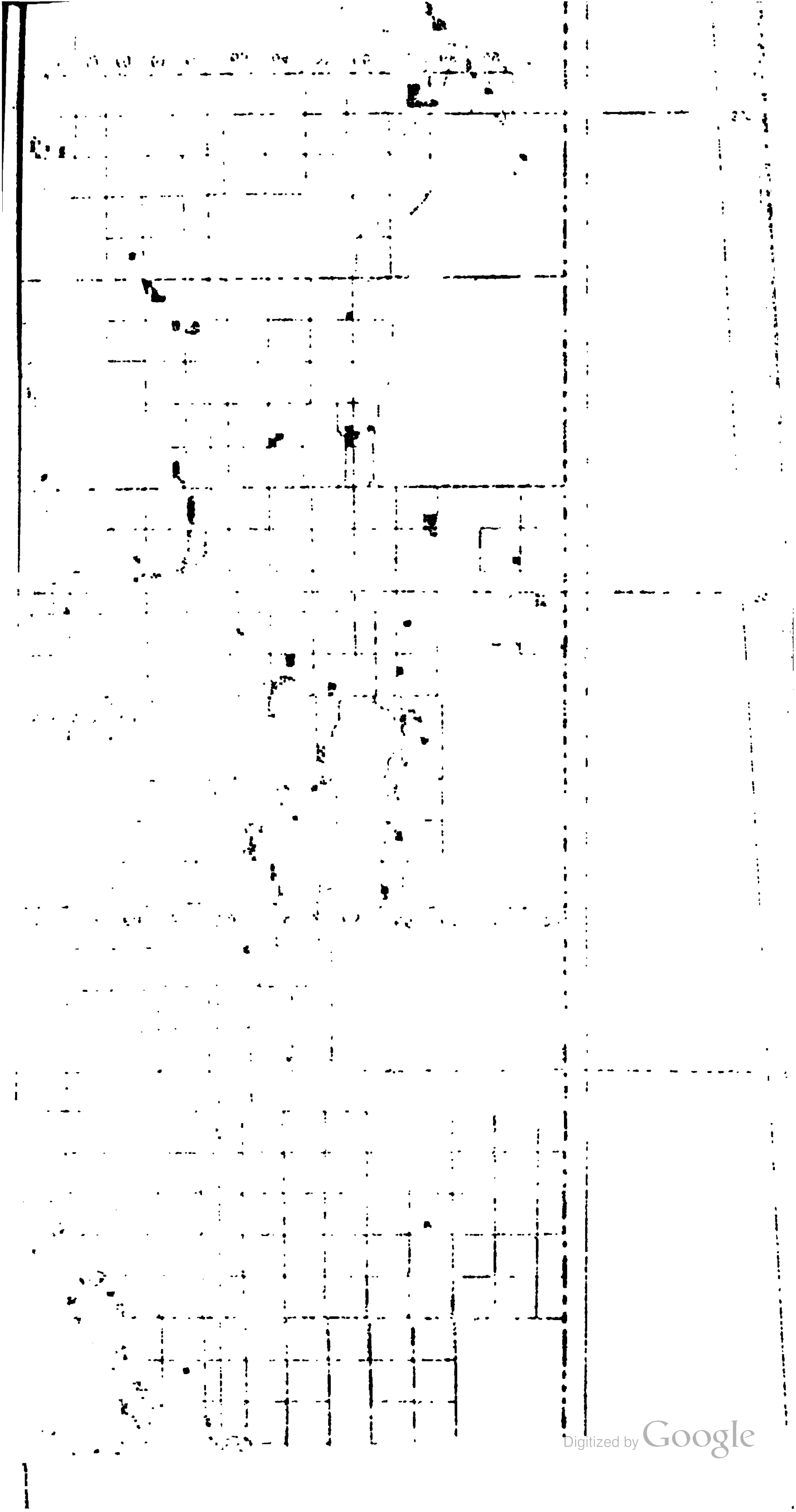

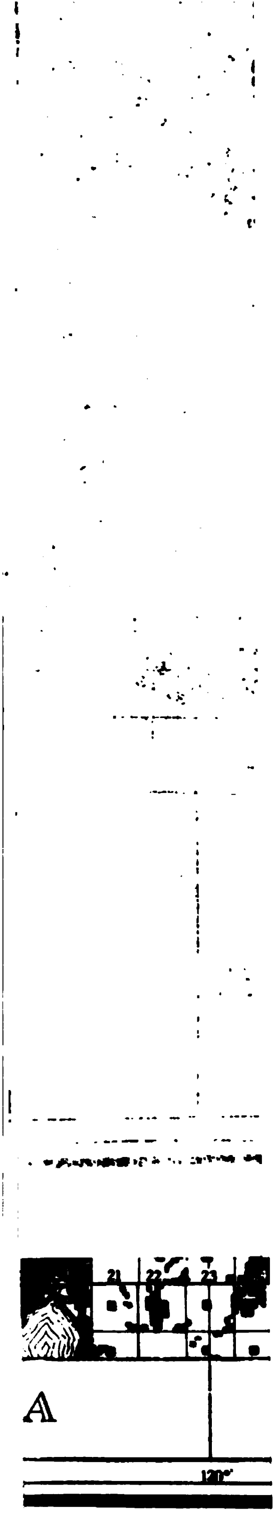

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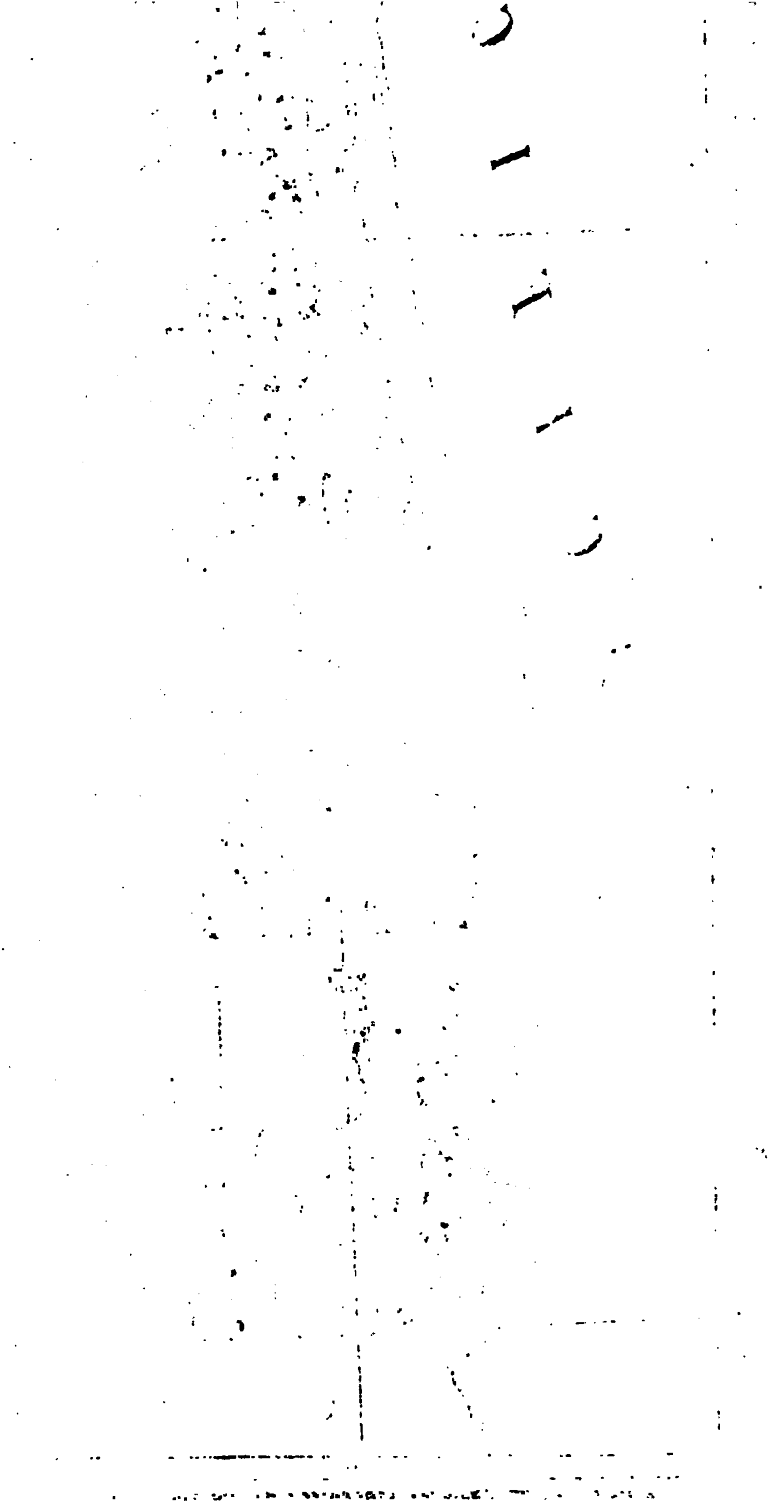

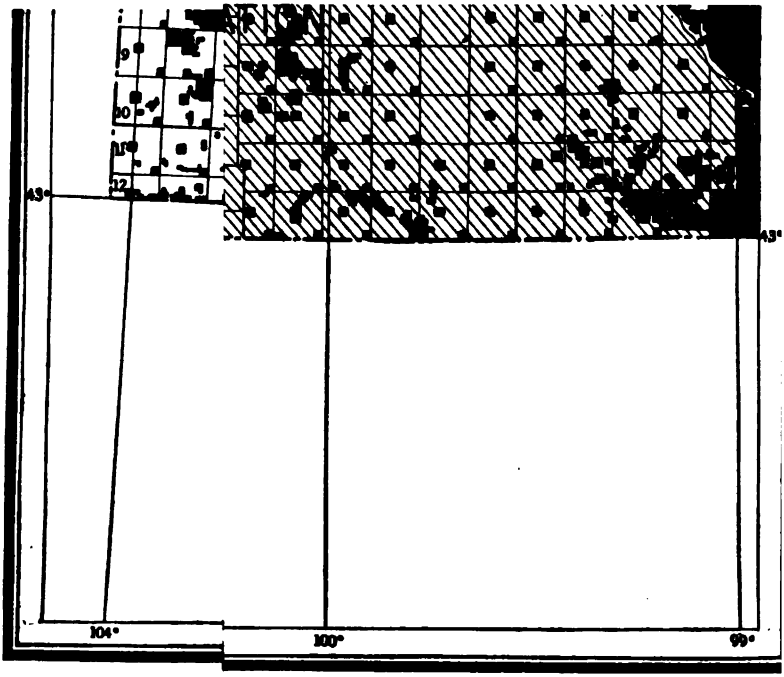
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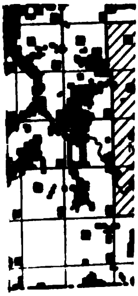

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